BYTE®

the small systems journal

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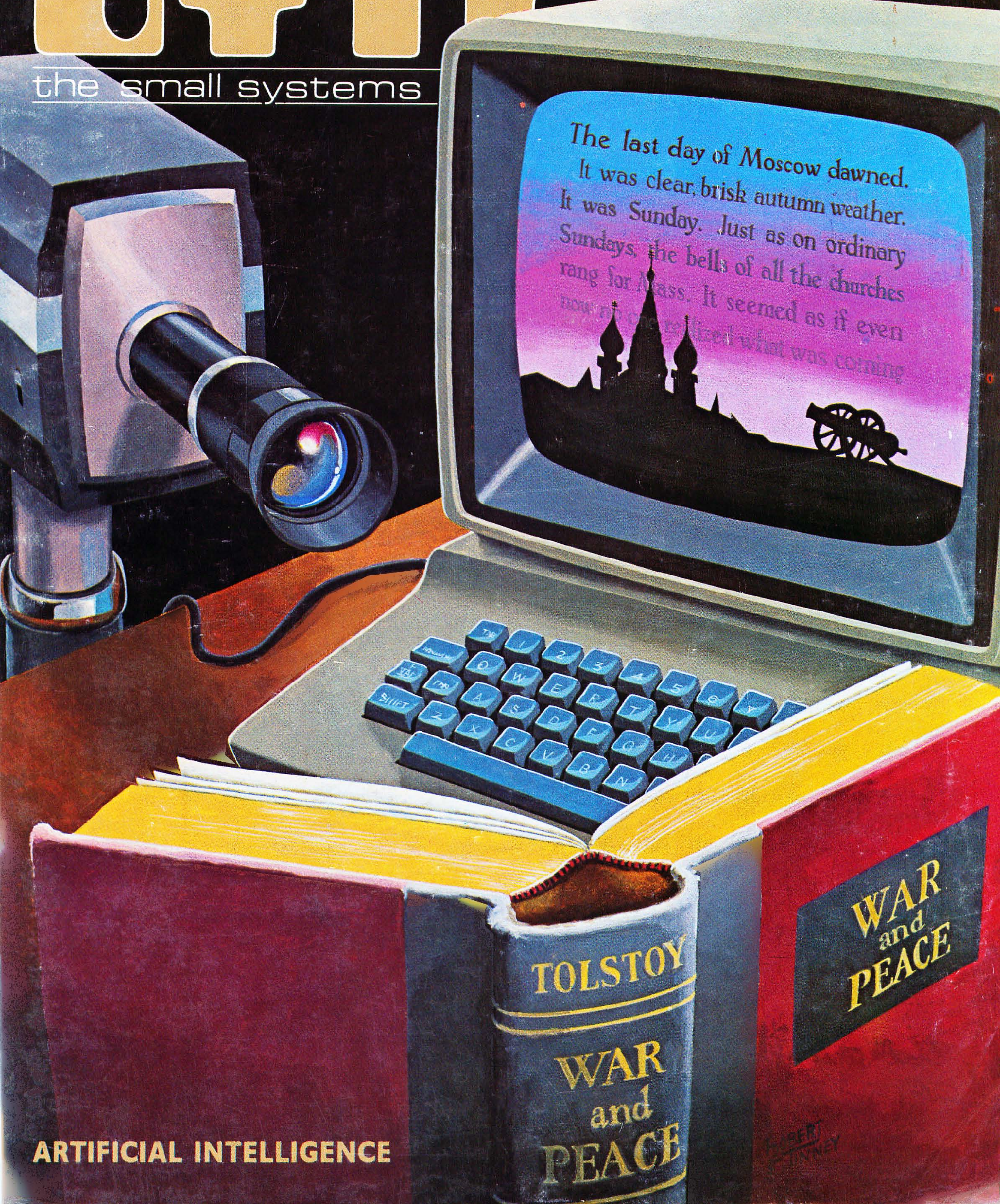
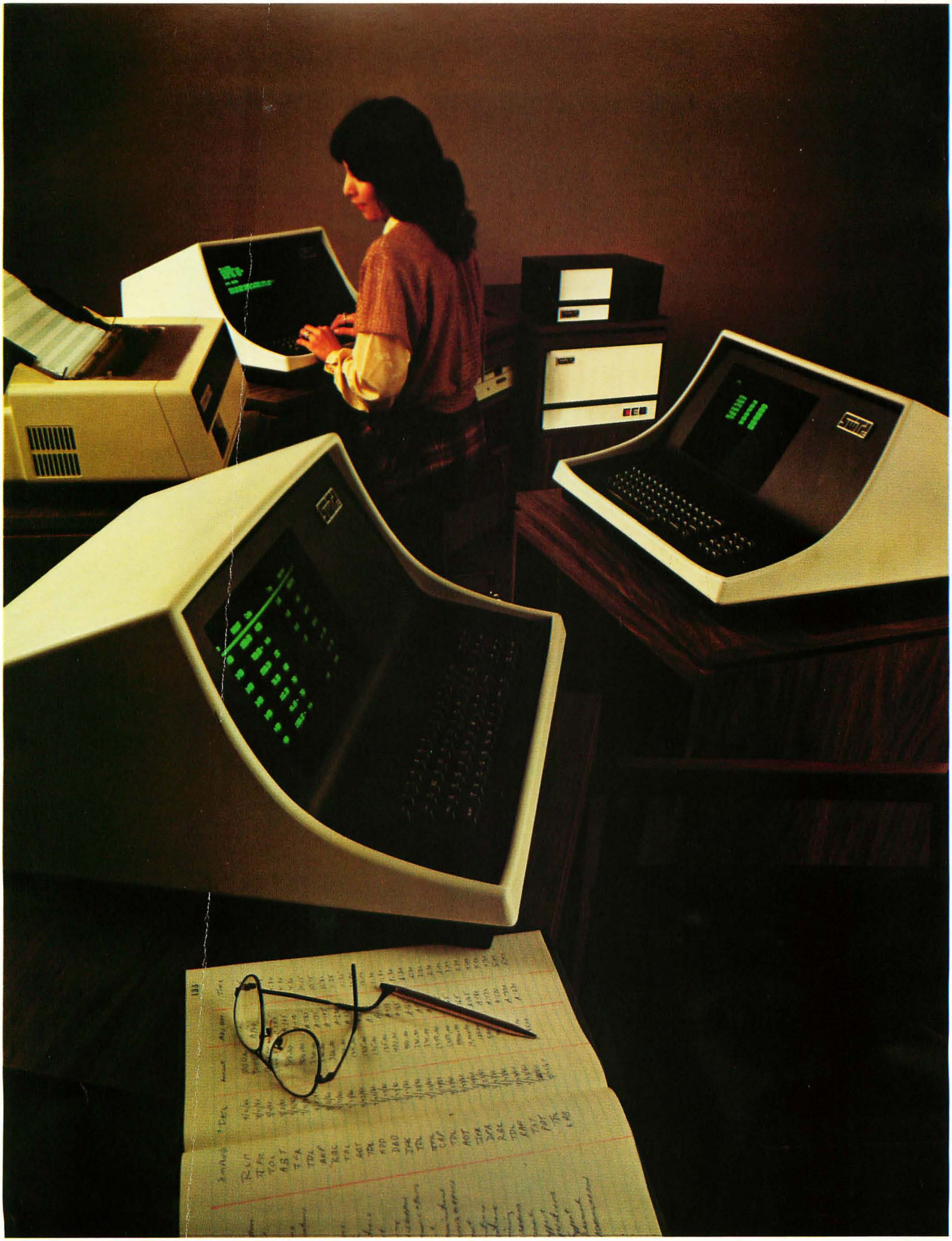
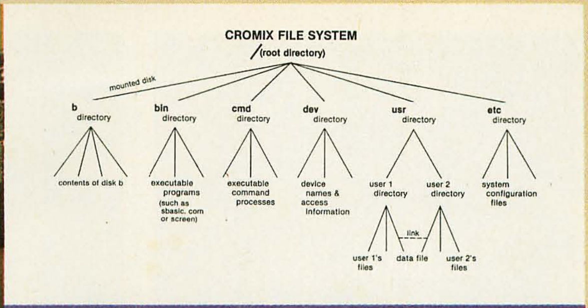
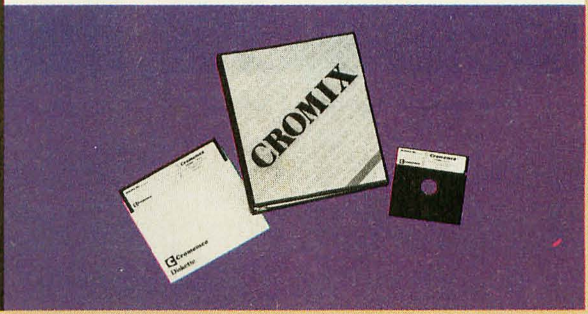


ARTIFICIAL INTELLIGENCE







CROMIX*— Cromemco's outstanding UNIX†– like operating system

CROMIX is just the kind of major development you've come to expect from Cromemco. After all, we're already well-known for the most respected software in the microcomputer field.

And now we've come up with the industry's first UNIX-lookalike for microcomputers. It's a tried and proven operating system. It's available on both 5″ and 8″ diskettes for Cromemco systems with 128K or more of memory.

Here are just some of the features you get in this powerful Cromemco system:

- Multi-user and multi-tasking capability
- Hierarchical directories
- Completely compatible file, device, and interprocess I/O
- Extensive subsystem support

FILE SYSTEM

One of the important features of our CROMIX is its file system comprised of hierarchical directories. It's a tree structure of three types of files: data files, directories, and device files. File, device, and interprocess I/O are compatible among these file types (input and output may be redirected interchangeably from and to any source or destination).

The tree structure allows different directories to be maintained for different users or functions with no chance of conflict.

PROTECTED FILES

Because of the hierarchical structure of the file system, CROMIX maintains separate ownership of every file and directory. All files can thus be protected from access by other users of the system. In fact, each file is protected by **four separate access privileges** in each of the three user categories.

TREMENDOUS ADDRESS SPACE, FAST ACCESS

The flexible file system and generalized disk structure of CROMIX give a disk address space in excess of one gigabyte per volume — file size is limited only by available disk capacity.

Speed of access to disk files has also been optimized. Average access speeds far surpass any yet implemented on microcomputers.

'C' COMPILER AVAILABLE, TOO

Cromemco offers a wide range of languages that operate under CROMIX. These include a high-level command process language and extensive subsystem support such as COBOL, FORTRAN IV, RATFOR, LISP, and 32K and 16K BASICs.

There is even our highly-acclaimed 'C' compiler which allows a programmer fingertip access to CROMIX system calls.

THE STANDARD O-S FOR THE FUTURE

The power and breadth of its features make CROMIX the standard for the next generation of microcomputer operating systems.

And yet it is available for a surprisingly low $595.

The thing to do is to get all this capability working for you now. Get in touch with your Cromemco rep today.

*CROMIX is a trademark of Cromemco, Inc.
†UNIX is a trademark of Bell Telephone Laboratories

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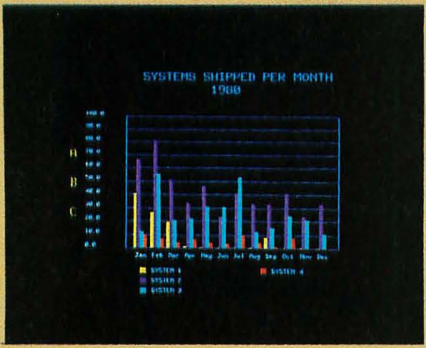
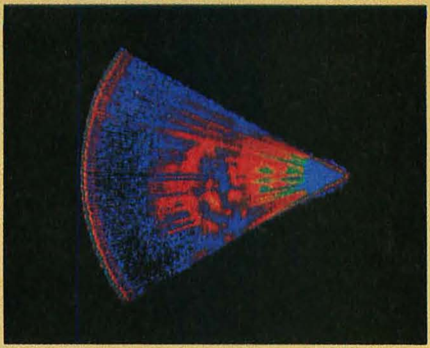
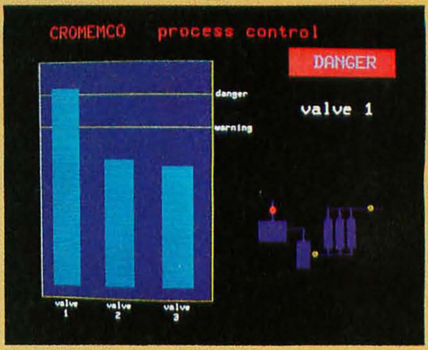


Management Information Display


Ultrasonic heart sector scan



Process Control

Get the professional color display that has BASIC/FORTRAN simplicity

LOW-PRICED, TOO

Here's a color display that has everything: professional-level resolution, enormous color range, easy software, NTSC conformance, and low price.

Basically, this new Cromemco Model SDI* is a two-board interface that plugs into any Cromemco computer.

The SDI then maps computer display memory content onto a convenient color monitor to give high-quality, high-resolution displays (756 H x 482 V pixels).

When we say the SDI results in a high-quality professional display, we mean **you can't get higher resolution than this system offers in an** NTSC-conforming display.

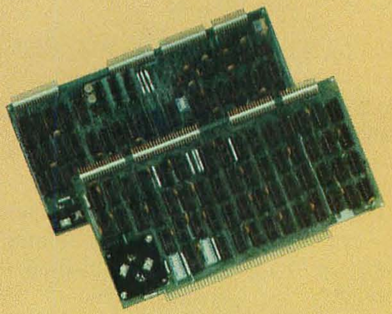
The resolution surpasses that of a color TV picture.

BASIC/FORTRAN programming

Besides its high resolution and low price, the new SDI lets you control with optional Cromemco software packages that use simple BASIC- and FORTRAN-like commands.

Pick any of 16 colors (from a 4096-color palette) with instructions like DEFCLR (c, R, G, B). Or obtain a circle of specified size, location, and color with XCIRC (x, y, r, c).

*U.S. Pat. No. 4121283


Model SDI High-Resolution Color Graphics Interface

HIGH RESOLUTION

The SDI's high resolution gives a professional-quality display that strictly meets NTSC requirements. You get 756 pixels on every visible line of the NTSC standard display of 482 image lines. Vertical line spacing is 1 pixel.

To achieve the high-quality display, a separate output signal is produced for each of the three component colors (red, green, blue). This yields a sharper image than is possible using an NTSC-composite video signal and color TV set. Full image quality is readily realized with our high-quality RGB Monitor or any conventional red/green/blue monitor common in TV work.

Model SDI plugs into Z-2H 11-megabyte hard disk computer or any Cromemco computer

DISPLAY MEMORY

Along with the SDI we also offer an optional fast and novel **two-port** memory that gives independent high-speed access to the computer memory. The two-port memory stores one full display, permitting fast computer operation even during display.

CONTACT YOUR REP NOW

The Model SDI has been used in scientific work, engineering, business, TV, color graphics, and other areas. It's a good example of how Cromemco keeps computers in the field up to date, since it turns any Cromemco computer into an up-to-date color display computer.

The SDI has still more features that you should be informed about. So contact your Cromemco representative now and see all that the SDI will do for you.

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In The Queue

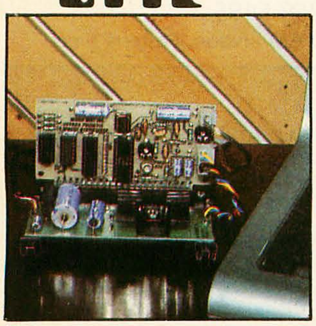
Volume 6, Number 9 — September 1981

Features

Reviews

Nucleus

BYTE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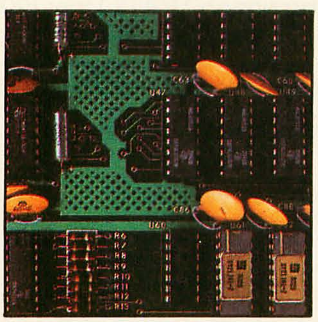
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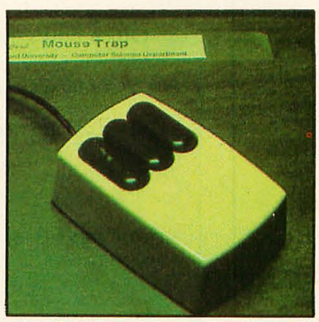

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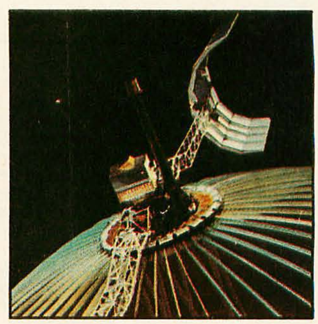
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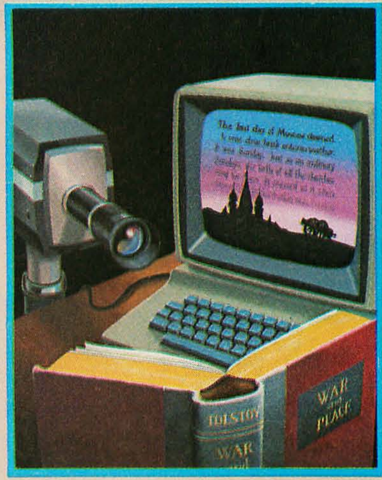

In This Issue

Computerized natural-language processing is one of the many topics that have come to be associated with artificial intelligence. As Robert Tinney's cover suggests, computers someday may be able to read and understand **War and Peace**. Steven Roberts' article "Artificial Intelligence" is a good place to start, and "Natural-Language Processing, The Field in Perspective," by Gary Hendrix and Earl Sacerdoti, addresses this month's theme. Donald Byrd discusses the point at which fact meets fiction in "Science Fiction's Intelligent Computers," and Ronald L Nicol focuses on the artificial intelligence community's primary language in "Symbolic Differentiation a la LISP."

Steve Ciarcia has prepared an alternate way of eliciting speech from a computer with "Build an Unlimited-Vocabulary Speech Synthesizer." We also have a description of the Xerox Alto computer by Thomas A Wadlow, and we take a look at NASA's high-flying computing machinery in Patrick Stakem's "One Step Forward—Three Steps Backup."

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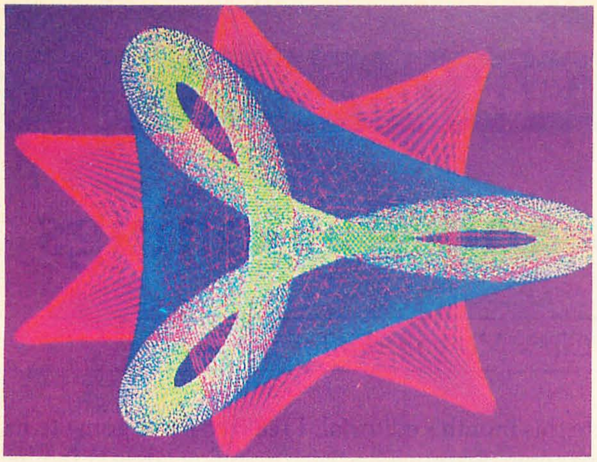
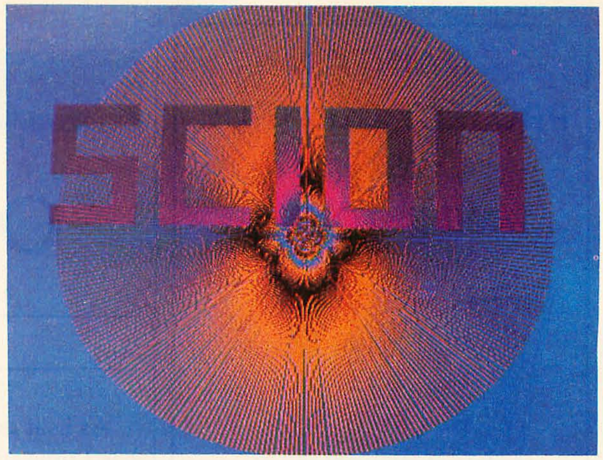
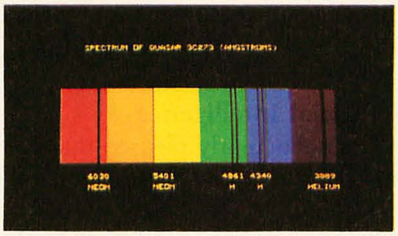




"...stands well above other S-100 graphics displays in its price and performance range."
BYTE, Product Review



"...better monochromatic ...display...."
ELECTRONIC DESIGN, 1981 Technology Forecast

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Local or external sync generation

4 Mhz Z80 microprocessor

60 hertz real-time clock

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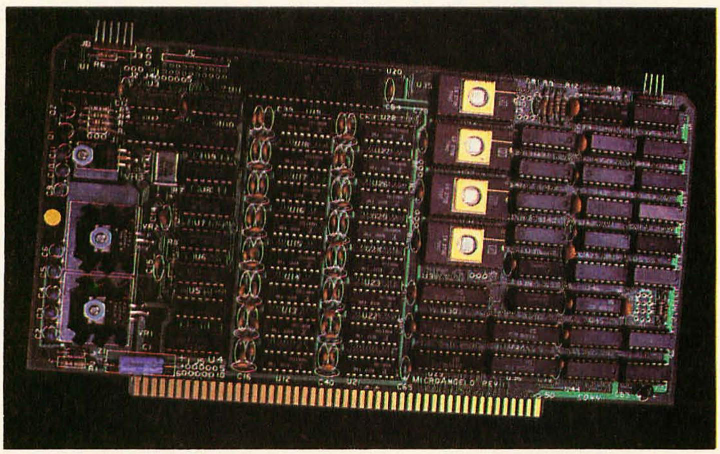

Light pen interface

Time multiplexed refresh

4K resident Screenware™ Pak I operating system

32K RAM isolated from host address space

High speed communications over parallel bus ports

Screenware™ Pak I

A 4K byte operating system resident in PROM on MicroAngelo™. Pak I emulates an 85 character by 40 line graphics terminal and provides over 40 graphics commands. Provisions exist for user defined character sets and directly callable user extensions to Screenware™ Pak I.

Screenware™ Pak II

An optional software superset of Pak I which adds circle generation, polygon flood, programmable split screen for separate graphics and terminal I/O, relative coordinates, faster vector and character plotting, a macro facility, full UCSD Pascal compatibility, and more.

And now...COLOR!!

The new MicroAngelo™ Palette board treats from 2 to 8 MicroAngelos as "bit planes" at a full 512 x 480 resolution. Up to 256 colors may be chosen from 16.8 million through the programmable color lookup table. Overlays, bit plane precedence, fade-in, fade-out, gray levels, blinking bit plane, and a highly visual color editor are standard.

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Editorial

Odds and Beginnings

by Chris Morgan, Editor in Chief

As I sat down to write this month's editorial, I realized I was going to have a hard time sticking to one topic. So much has been going on lately, I thought I'd throw it all into one convenient column. The title "Odds and Beginnings," which I stole from James Thurber, reflects this potpourri.

Artificial Intelligence

I'm particularly pleased that we were able to fit so many interesting articles about artificial intelligence into this month's issue. Many of them were commissioned at last year's AAAI (American Association for Artificial Intelligence) meeting at Stanford. In particular, the articles "Natural Language Processing: The Field in Perspective" (page 304) and "Knowledge-Based Expert Systems Come of Age" (page 238) discuss topics that, in my opinion, have not received the coverage they deserve. A personal computer's ability to understand at least rudimentary English will be important to the future of programming. Similarly, a computer that can give advice and act as an "expert" on a given topic raises some profound and difficult questions. Some of these issues have been dealt with in science fiction, and Donald Byrd explores them in "Science-Fiction's Intelligent Computers" (page 200).

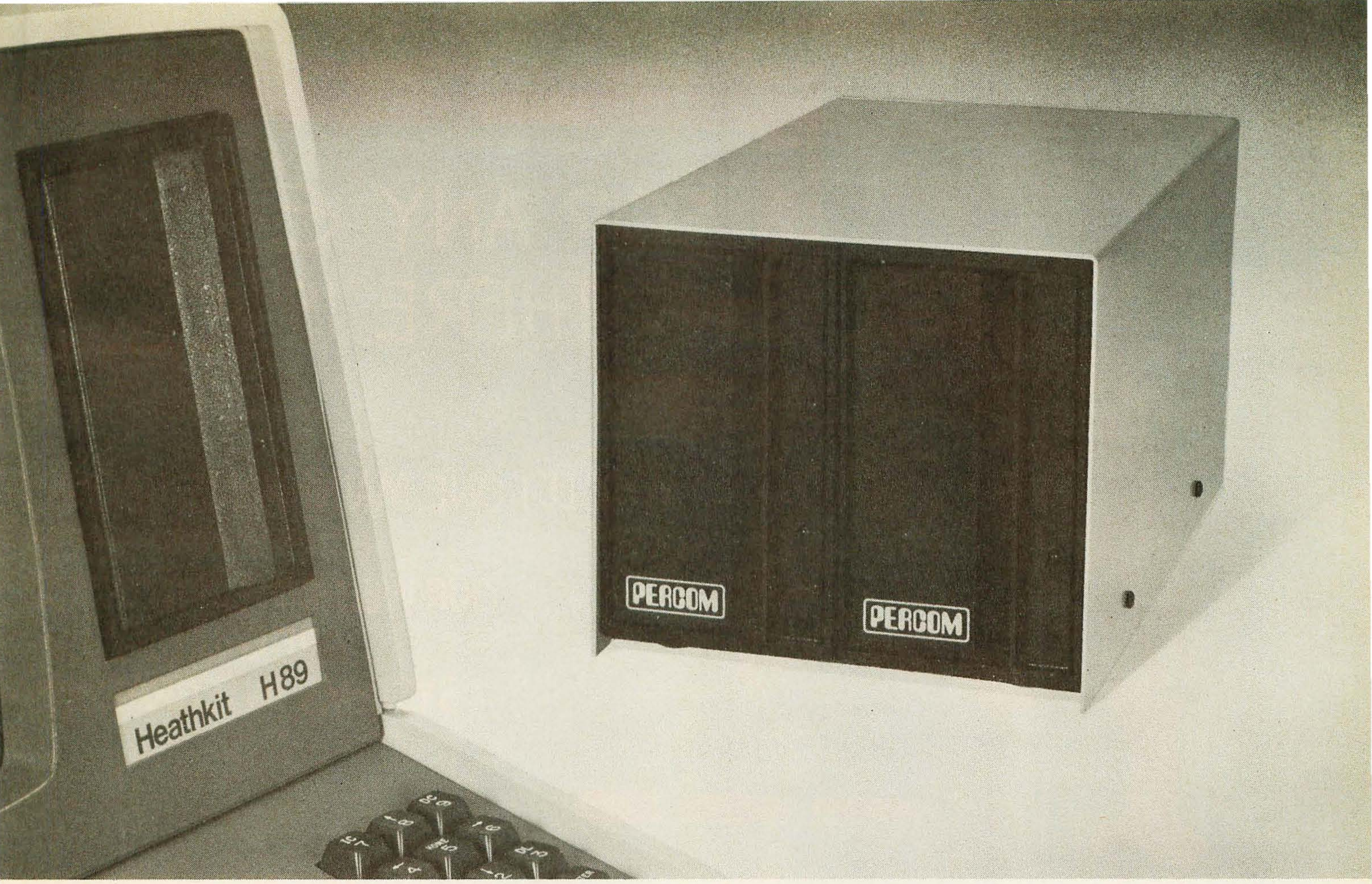
Computer Shows

I've been on the road quite a bit this spring and summer attending computer shows. As always, the West Coast Computer Faire in San Francisco was of great interest. Anyone doubting the vitality of our field need only walk into this show to be struck by the level of enthusiasm. If you want to track the progress of personal computing, go to the West Coast Computer Faire and watch the number of exhibitors expand and the wide-eyed visitors become more wide-eyed each year.

The NCC (National Computer Conference) was held in Chicago this year, and it was easily the most spectacular show yet. (See the two-page photo essay beginning on page 36.) The "star" of the show, attracting a constant enthusiastic crowd, was the Xerox Star terminal, which single-handedly advances the state of the art in terminal design for the office. Many of the system's features recall those of the Smalltalk systems (see last month's BYTE, devoted to the Smalltalk-80 system) I saw at Xerox PARC (the Palo Alto Research Center). The Star system, which will cost $16,595 for the standard unit, treats all documents, files, etc as concrete "objects" that can be manipulated by the user. Its software structure resembles a nest of boxes, each box containing more and more complex information about the workings of the system. Users need penetrate only to the box they require to do a particular job, thus avoiding information overload.

Clever user-interfacing devices abound on the Xerox Star, including a "mouse," a mechanical box with wheels that can be rolled around on the desktop to position the cursor on the screen. I could go on at length about the features of the machine, but I must move on. An excellent treatment of the Star can be found in the April 27, 1981, issue of the Seybold Report, a twice-monthly report that consistently offers the field's best coverage of word processing, computerized typesetting, and office automation. The report costs

Editorial continued on page 10



Introducing the Z Line . . .

Now! Percom Drives for Heath Computers.

Percom's now making add-on drives for your H-89 and H-8.

Complete drive systems will be available soon.

If your immediate need is for add-on storage, check the features of our fully compatible Z drives.

If you plan to add a complete disk system, watch for the imminent announcement of our double-density Z Controller.

Given a choice, we think you'll choose from the Percom Z line.

Add-On Z Drives

- Available in 40- and **80-track** densities, in 1- and 2-drive color-compatible modules.
- All drives are rated for single- and **double-density** operation.
- Some models accommodate **flippy storage**, allowing you to flip a diskette and store files on the second side.
- Fully tested both electrically and mechanically. Plus, all Z drives receive a 48-hour **operating burn-in** to uncover latent defects. Look for the signed quality assurance slip.
- Low prices: Fully assembled and tested, one-drive units start at only $399, two-drive units from only $795.

Z DRIVES FROM PERCOM: THE BEST ONES FOR YOUR ALL-IN-ONE

Model	Number Tracks one side	Formatted Strg. Cap. SD	Formatted Strg. Cap. DD	Features
ZFD-40™	40	102K	180K	Low price, fast step time
ZFD-80™	80	205K	364K	Max. stg., fast step time
ZFD-100™	40	102K	180K	Flip-side diskette storage

SYSTEM REQUIREMENTS: H-89 or H-8 computer with 16 Kbytes of RAM, Heath first-drive floppy disk system, Heath disk-operating system and drives interconnecting cable. (Two-drive interconnecting cable optionally available from Percom). ZFD-80 drives include a program patch on diskette to modify HDOS for 80-track operation.

PRICES AND SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE.

Available Soon!
Percom's Low-Cost Double-Density Z Controller.

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Yes . . . I'd like to know more about Percom Z drives and the Z Controller. Rush me free literature.

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B01

A simple algorithm

We work with the serious systems integrator ... on terms that make sense to you. That means giving you a set of products which expand your limits, not reduce them.

We manufacture the most complete family of high quality IEEE/696 S-100 mainframes on the market. Choices include three mainframes in rack-mount or table-top packages with complete board sets, to serve as the building blocks for your 8 or 16 bit system. We also provide other options ranging from complete floppy disk systems right up to our proven Pascal development system.

The ∫ factor: one source.

No matter which option you choose, you get the benefit of working with completely integrated products ... fully assembled and tested ... under one warranty and one price structure ... leaving you free to concentrate on value-added application development and sales.

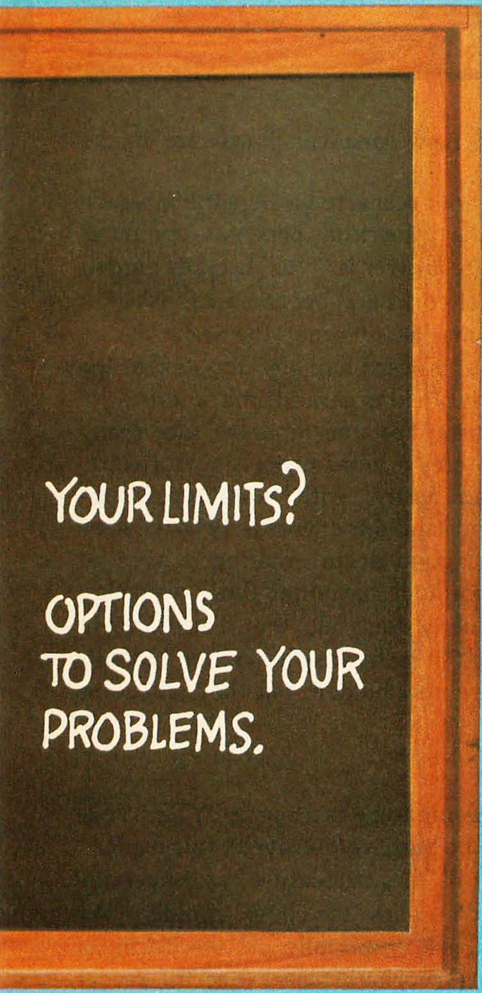
Choose from mainframe options ...

Select from three packaging options: Rack-mount, table-top or front panel models. All three feature our 20 slot S-100 motherboard with 25 amp power supply and are delivered fully assembled and tested with our Series II™ board sets. Any board configuration you choose works with any DPS-1 version, allowing you to vary your package offering, or develop on one version and market another.

- Front Panel model — a powerful development and diagnostic tool for Z-80† systems, which can be used for prototyping, servicing, debugging, and software or hardware development. Use its features to set breakpoints, trigger scopes, single step, slow step and more.
- Front Panelless desk top model—a lower cost option for OEM or other turnkey operations which do not require the extra capability of our Front Panel.
- Rack Mount version — features a heavy gauge frame designed to fit into standard 19" racks. CVT power supply for brown out immunity is standard.

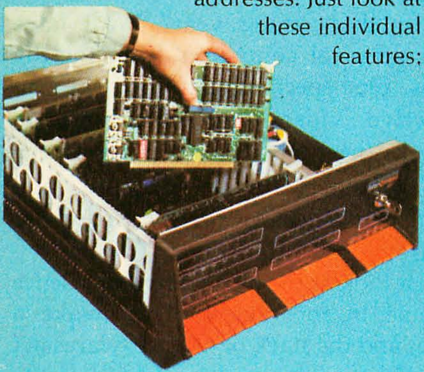
*In Calculus, a fundamental statement in the definition of limit; interpreted here to imply: "For your integration problem, Intersystems has a solution."

† Registered trademark of Zilog, Inc.



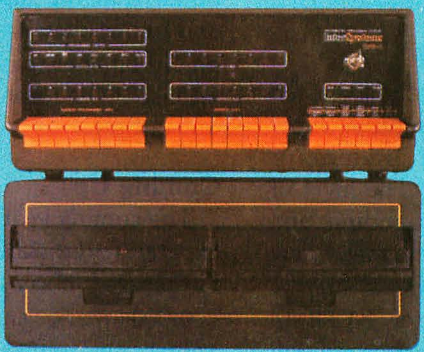
Board level options...

Intersystems mainframe packages, equipped with Series II boards, are operational in both 8 and 16 bit settings and support extended addressing in both I/O and memory space, recognizing 16 bit I/O addresses and 24 bit memory addresses. Just look at these individual features;



- MPU-80—uses a Z-80, 8 vectored interrupt lines and two 4K windows to address up to 1 Megabyte of RAM without bank select.
- 64KDR—sophisticated refresh circuitry allows unlimited DMA and absolutely reliable operation without wait states.
- 6 SI/O — six individually software-controllable serial I/O ports with optional interrupts. Each can run RS 232 at up to 19,200 BAUD, as can our VI/O board.
- VI/O—has two serial ports; two 8-bit parallel output and two 8-bit parallel input ports plus 8 individually controllable command lines and 16 levels of vectored interrupts.
- FDC II—can DMA up to a full track into 16 Megabytes of memory. Optionally generates interrupts and handles up to four 8" floppies.
- MPU-8000 — available with the non-segmented Z-8002†, which directly addresses 64K, or the segmented Z-8001†, which can directly address 8 Megabytes.

Extended systems options...



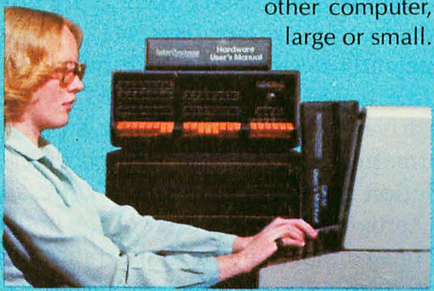
Interfacing disk drives is not a trivial matter, so when your objectives and resources dictate you spend your energy elsewhere, use our resources to perform the service for you. We can add our disk drive package to any Z-80 or Z-8000 configuration we provide ... again, fully assembled and tested and covered under one warranty.

Or our complete Pascal Development System.

We use it for our own hardware and software development. It includes either table-top mainframe, two 8" floppy disks, 128K RAM, CP/M#, and Intersystems Pascal/Z™ compiler and Cache BIOS™.

THIS SYSTEM IS FAST! Why? Because our ultra-fast Cache BIOS automatically buffers whole tracks, eliminating most disk accesses. This delivers up to three times the throughput of any other floppy-based system we know and is equal to many small hard disk systems.

The system is versatile, too. SET program allows you to change many BIOS parameters and specify control characters to enable special features such as diagnostic output to trace program execution. It can also provide remote I/O to link your system to almost any other computer, large or small.



And it's reliable. The Cache BIOS System runs continuous memory tests when idle, and verifies with a Read after Write and Read after Read.

And the system also includes our Pascal/Z, a true native compiler producing ROMable and Re-entrant code. It features a minimum of extensions chosen for the development of your scientific and business applications. And it's compatible with our native code Pascal for Z-8000, providing a graceful upward path to 16 bit applications. So what you write now is right later.

One choice you won't have to make...

We don't believe you should ever have to sacrifice good technical support to find a good product. We'll back you to the hilt with services like free technical consultation, board-swapping, diagnostic packages, and documentation that gives you all you need to integrate, operate and maintain your system ... right down to schematics of the boards.

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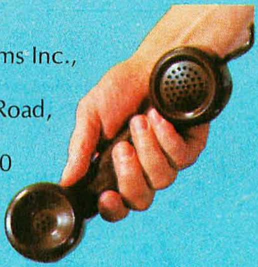

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$175 a year, and subscriptions are available by writing Box 644, Media, Pennsylvania 19063.

In contrast to the Star, the recently unveiled Xerox 820 personal computer (see page 441) is disappointing. It's a competently designed machine but very "plain vanilla," sporting a Z80 processor, CP/M, two 5¼-inch floppy disk drives (which give the user a paltry 92 K bytes of unformatted storage per floppy disk), and no high-resolution graphics. What the 820 *does* do, however, is give Xerox a foot in the door of the under-$3000 market. And one cannot deny the importance of the 820's ability to interface with the Ethernet system, Xerox's information network that will most likely become the standard for high-end local networks. We'll have more information about the 820 in upcoming issues.

Japanese Market

Senior Editor Gregg Williams and I recently spent ten days in Japan attending the Tokyo Microcomputer Show and visiting more than ten companies that produce, or are about to produce, personal computers. The level of interest in the microcomputer in Japan is astounding, and the trip was a revelation. We will be reviewing many new Japanese machines and analyzing their effects on the American marketplace in a special issue of BYTE to appear early in 1982. Watch for it. In addition, we will present a roundup of new American hardware in the January 1982 issue.

The question of the hour seems to be "Are the Japanese going to dominate the American personal computer market?" My immediate answer is "No." It takes time to develop distribution networks and become established in this highly technical market—it's not the same as the automobile market. But if ever I had any doubts that the Japanese had entered our field in earnest, the doubts were dispelled during the trip. Yes, the Japanese face many obstacles. In order to create word-processing software, they need more familiarity with our typewriter-dominated office systems and more sensitivity to the need for good software and good documentation. I have no doubt that the Japanese will surmount these obstacles, and in fact they are quietly doing just that. According to an old Japanese saying, "It is the wise hawk that hides its talons." The talons are now hidden, but they will come out in time.

Coming Up

The coming year is going to be exciting at BYTE. We're expanding our staff to be more responsive to our readers. I'm pleased to say that BYTE's circulation has topped the 200,000 mark and continues to climb rapidly. We appreciate your feedback, especially in the form of BOMB votes for your favorite articles. (See the reader service card at the back of the magazine for an explanation of BYTE's BOMB.)

One of our major projects this year has been transforming *onComputing* magazine into *Popular Computing*, a new monthly magazine that will appear this November. It's designed for the nonspecialist and will cover the entire spectrum of popular computing for the benefit of professionals, business people, educators, and interested laypeople. We're particularly proud of the new *Popular Computing* staff stationed around the country to keep readers up to date.

What's in store for the coming year? We'll have coverage of the new personal computers from the big mainframe companies, plus special issues about human engineering, interactive videodisks, computers in business, local networks (next month), computers in the humanities, games, computers for the disabled, and much more, including our extensive review section for hardware and software.

Incidentally, I took a look at the new computer science books that have come in for review. They make a stultifyingly large pile, and the stack of new software isn't much smaller. But we're working to keep ahead of the game.

Another perennial interest at BYTE is computer graphics. By the time you read this, I will have attended the ACM's SIGGRAPH conference in Dallas. Watch for a full report featuring some of the most exciting graphics we've ever seen. ■

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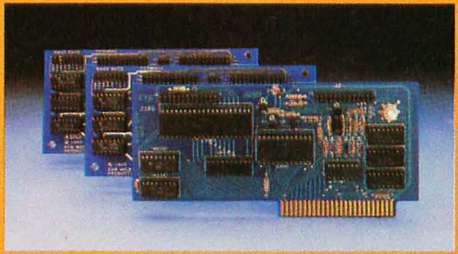

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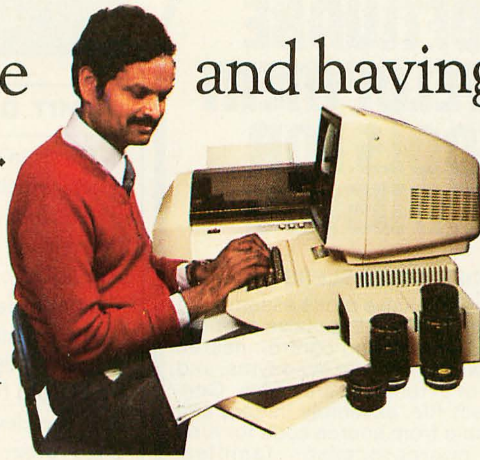
cutting down on shared time and having his own tamper-proof data base.



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Letters

MIT Defends Logo Policy

This is in response to Mr Stephen Hain's letter, which appeared in the August 1981 BYTE and which raised questions about the release and distribution of the MIT Apple Logo programming language. (See "Unpublished Apple Logo," page 32.)

As correctly noted in the original BYTE article ("Logo for Personal Computers," by Harold Nelson, June 1981 BYTE, page 36), the development of the MIT Apple Logo programming language was sponsored in part by the National Science Foundation (NSF). Discussions between MIT and NSF with respect to mechanics of release and distribution have been underway. Licensing authority has now been formally requested by MIT; and, as soon as permission is granted, it is the intention of MIT to complete licensing arrangements that will ensure the broadest possible dissemination of this important programming language.

Kenneth A Smith
Associate Provost
MIT
545 Technology Sq
Cambridge MA 02139

Comments on Software Piracy

The following comments by our readers were solicited through Chris Morgan's May 1981 BYTE editorial "How Can We Stop Software Piracy?"

I commend Chris Morgan and BYTE for addressing a subject too frequently overlooked. Software piracy has, indeed, reached an appalling level, while somehow retaining an odd sort of tacit protection—that of being a "gentleman's" crime.

Chris Morgan's statement that "software piracy . . . is not just illegal—it's unethical" couldn't have been more to the point. It *is* unethical. Shamefully so. To those who attempt to protect their works, this can't be stressed enough. The courts and various legal bodies are slow, but they are working toward resolving some of the piracy problems. Many talented people are working madly devising clever tricks to prevent the theft—all because there are those who think it's better to have something for nothing than it is to ethically exchange with those who worked hard to produce something of value.

No doubt the thieves have justified their actions. Maybe they think the "system" is unfair; maybe they think they can't afford the programs they so dearly want; maybe they don't even think at all. But one thing is certain: they haven't developed software packages themselves and then had them ripped off to the tune of thousands of dollars. That much we know.

It's a shame that one's fellow man is called upon to police another. One would like to believe that we're fair and honest people. It appears not all of us are. Hence, in addition to the efforts of our legislators and programmers, those ethical souls who learn of piracy need to do something effective about it. If simple reasoning with a software pirate won't do it, then reporting the matter to the developer just might. While contrary to the childhood dictum "don't be a tattletale," it could help to curtail a growing cancer in the industry.

The Association for Software Protection (ASP) is a newly formed group dedicated to eradicating the piracy problem. At present it is addressing—in the main—the problems faced at the minicomputer level. Nevertheless, the piracy problem branches across all levels, and any group or individuals interested in organizing an antipiracy microcomputer group are invited to contact ASP.

In addition to my activities with ASP, I am the Software Protection Director at Mini-Computer Business Applications in Glendale, California.

Robin Robinson
Association for
Software Protection
10143 Leona Ave
Tujunga CA 91042

Chris Morgan's and BYTE's concern with software piracy is well placed, and BYTE's coverage is excellent, but there are wider perspectives to add.

For millennia, humanity moved around picking and chasing things to eat. The Agricultural Revolution meant the complete transformation of social arrangements, which resulted in the invention of private property, towns, political institutions, writing, ruling classes, fortifications, the ownership of land, etc.

Things were like that for a few millennia more. For the last couple hundred

Letters continued on page 18

TWELVE STRONG
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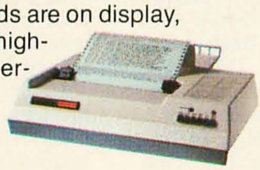

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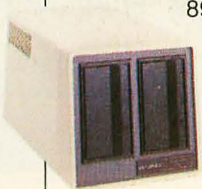
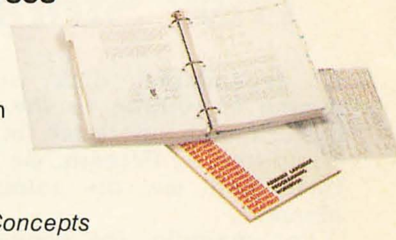


The 5¼-inch 87 Dual Disk System adds 200K bytes of storage to your 89. Both disk systems feature read/write protection and easy plug-in adaptability.

8. Self-Study Courses



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years, however, most people have run machines. As we see and know, every society and culture in the world has been thrown into turmoil because, once again, the world is changing rapidly.

"Classic" economics is based on *material* commodities: if there are you and me and a loaf of bread, either you get it, or I get it, or we split it. No existing school of economics, however, deals with the fact that if you give me some information, you still have it. Material commodities get "thinner" when spread out, while information gets "thicker" as it's spread out.

Two-thirds of the jobs in the United States are informational. Money, property, and many other foundations of society have begun transmuting. Software piracy is a logical area for difficulties to emerge first. Where else can you go into business selling pure thought?

The more we are aware, and the more we examine and discuss the big implications, the less surprised we'll be.

Neil Rest
1457 Gregory
Chicago IL 60640

Congratulations to Chris Morgan for his timely attention to the software-piracy controversy. The following specifications may be useful in evaluating solutions proposed for this problem:

- There shall be no realistic means for defeating the protection mechanism, regardless of the attacker's technical sophistication or familiarity with the design of the software-protection system.
- The software product shall *not* have to be customized for each licensee.
- The user shall have to purchase one, and only one, hardware device to use *all* protected software. Once this device is attached to the computer, the user shall be able to forget it exists.
- The device shall be the same, regardless of the computer system with which it is used; and it shall be compatible with existing computer systems.
- There shall be no degradation of the reliability or versatility of a computer system as a result of this device.
- The cost of the device shall be minor compared to the cost of the least expensive (but practical) system on which protected programs will be used.
- The logistical support of the protection system shall require no effort on the part of the software publisher.
- The system shall restrict the use of protected software to the licensed user for a licensed period of time.

I would appreciate the comments of BYTE's readers on the applicability and completeness of these specifications. At Salcris Corporation, we are currently field-testing our Chrono-Guard Software Protection System, which meets these specifications. Software protection is our only business and, while we believe we have a carefully thought-out solution to the industry's problems, we value constructive criticism.

Thomas C Donald
President
Salcris Corporation
1 Office Park Cr
Birmingham AL 35223

In the May 1981 BYTE there were several excellent articles on what I regard as one of the most severe problems facing the computer-software industry today—theft of software. (See Chris Morgan's "How Can We Stop Software Piracy?", page 6; Christopher Kern's "Washington Tackles the Software Problem," page 128; and Stephen Becker's "Legal Protection for Computer Hardware and Software," page 140.) I know of several companies, mine included, that will not sell packaged software because of the theft problem. The constant "reinvention of the wheel" that results from the reluctance to sell software is one of the leading factors contributing to the already poor productivity of the industry. If we are not to stagnate and allow foreign competition to steal our software lead, an early solution to this problem must be found.

One article mentioned several rather complex hardware solutions that are currently proposed to help solve the problem. While most of the hardware discussed would provide more or less processor-independent solutions that would require no industry-wide effort to help solve the problem, I feel that these efforts will lead to an expensive and relatively insecure solution. The cheapest and most reliable answer is not a hardware solution (although hardware must play a key role), but "self-protecting" software.

How can software be made to protect itself? Well, I am not aware of any processor on which this is possible today, but a minor processor modification could easily, cheaply, and effectively accomplish

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this. The biggest problem will be to get everyone to cooperate and adopt a standard approach.

IBM was on the right track to solving the problem several years ago, but someone, somewhere, dropped the ball, and the solution became only half-implemented. Anyone who has ever done some systems programming work on an IBM S/370 is probably aware of the privileged instruction "STORE PROCESSOR ID." This instruction provides systems programs with the processor serial number and other system information, such as whether VM/370 is the system-control program, etc. This instruction provides system-level programs (and even microcode) some degree of theft protection, although its primary purpose is to provide a method by which system programs can determine what model processor is being used. The big problem from the applications program side, which is where IBM left the scene, is that there is no easy method to access the information provided by this instruction.

To solve the software-theft problem, the entire industry must provide some method by which the user's application program can determine such information as the make, model number, and serial number of the host processor. Additionally, it must be constructed in a manner such that it would be next to impossible for the user to modify the factory-supplied information. The addition of one instruction to the processor repertoire would undoubtedly increase the cost of the hardware, but the increase would not even approach the price of the cheapest protection method that I have seen proposed. The only disadvantages to this approach are that it would not be easily applicable to existing systems (most of which will probably not be around more than five years anyway, so why worry?) and it would preclude the distribution of source code (you would not want someone to discover how you encrypt the processor ID and check against the licensed processor ID).

I welcome any comments.

Jon R Kibler
President
Southeastern Computer Services Inc
POB 160124
Mobile AL 36616

Chris Morgan's May 1981 BYTE editorial mentioned a software-protection

scheme based on encrypting programs.

Since mid-1979, all Sentinel computers have used a somewhat more convenient scheme. In our systems (based on one or more Intel 8086s), the machine's serial number is available to the operating system. The operating system recognizes encrypted application programs and uses the serial number as a key to decrypt them as they are loaded from floppy-, Winchester-, or bubble-memory-disk storage.

This protects Sentinel's investment in our comprehensive set of financial application programs and lets us give our distributors and end users utility programs that can copy any of our software.

We also give Sentinel distributors the tools to encrypt their own programs.

Vernon J Schryver
Product Development Manager
Sentinel Computer Corporation
9902 Carver Rd
Cincinnati OH 45242

I read Chris Morgan's editorial on software piracy with interest. The two sides of the software protection/duplication controversy were drawn as "the vendor's need for security" versus "the user's need for backup copies for reliability."

My experience with software products, both large and small, has revealed an even greater need on the part of software purchasers than that of backup copies. This need is for *modifiable* and *configurable* software. A few years ago, most small-computer systems were either home-built or installed and used without modification from the time they left the factory. In the case of personal computers, peripherals were few and were usually made or distributed by the frame manufacturer. Things are different today—and this has given rise to the need for user-configurable software.

For example, my firm's Apple II computer contains interface cards for four peripheral devices: the disk system, printer, modem, and an 80-column video card. Only one of these is an Apple Computer product. Nearly every software product we have purchased has required reconfiguration—sometimes a lengthy project—to support these devices.

I am very reluctant to purchase any software packaged on a copy-protected disk, an "unreadable ROM," or otherwise immune to modification to suit our needs. Vendor support of nonstandard hardware is an admirable goal, but we realize that it

One Man's Dilemma

I would never break into a computer store and steal a disk drive, a printer, or a processor card. After all, I'm a decent, intelligent, honest person. I teach my children the value of personal integrity, and I pride myself on my honesty. I never keep overpayments. I pay my taxes. I even spent over six months convincing a large department store that I owed it money when it couldn't find any record of the transaction. I don't allow my children to make audio-tape copies of records for each other. After ten years in the entertainment industry, I know how valuable a copyright is to a performer.

So, how did I become a software thief?

It started when I sold my Altair Tarbell cassette machine and upgraded to a North Star disk-based system. I knew when I got the system from a friend that he had piles of software to supply in the deal. That was the main reason I worked with him—to get the software. There were about twenty disks full of BASIC games, business programs, and a word processor. A neat little assembler and disassembler were included, although my primary interests were word processing and BASIC. I rationalized it this way: I would never do any commercial work using any of the programs. I was just learning—sort of "test driving." If I did decide to do any serious programming, I would purchase what I needed to keep everything legal. I was, after all, an honest man. It worked too well and for too long.

It wasn't very long before I had forgotten my commitment; moreover, I wasn't doing any serious work on my computer. I did buy an updated version of North Star BASIC from the factory, which sort of made me legitimate. Things were stable for about a year, with no exchanging or sharing.

Then, I had a letter published in a magazine where I casually mentioned I would be interested in exchanging programs. Before I knew it, I had a growing file of others interested in "sharing" what they had. This list eventually focused on an individual in Michigan who seemed very generous and quite sincere in helping me not only get software, but in getting it up and running. Over a three-month period this relationship blossomed into a friendship. I was very grateful to this person. I was doing most of the receiving and only minimal giving, but he didn't seem to mind. There are people who get pleasure out of helping others.

I was about to submit a software review to a magazine when I was confronted with the stark truth: I was a thief. I don't know if the fear of being found out is what motivated me to take a long, serious look at my past actions. But whatever it was, I was faced with three problems:

- *I had received stolen goods.*
- *I required these stolen goods every time I turned on my computer. This meant that if I decided to change my position, I would have to purchase a license and become a legitimate user of several hundred dollars' worth of programs.*
- *The explanation I would have to give to my Michigan buddy. How could I take his generosity and tell him that, for me, it had become criminal?*

I prepared a letter, and, as fate would have it, he called me while it was in the mail. I had to tell him what I had spent so much time carefully wording. I felt trapped. Finally, I began to unfold how I felt about exchanging software. I explained that mine was a unilateral decision and wasn't meant to push him into a similar repentant attitude. It was wrong for me but not necessarily everybody. The words came out, and he seemed to take it very well and understand my position. It was several months before I heard from him again. When I did, he wasn't very friendly. It was an impossible situation.

This is the number one problem in stealing software: You cannot do it alone. Someone knows you will compromise your values if the price is right. Maybe even worse, you know you are helping other people compromise their values.

During this particularly difficult time for me, I remembered something my dad had told me when I was a boy. We had just left a friend's ranch after hearing how he had been paid for two cases of eggs he never delivered. My dad said, "If a man will cheat somebody else, he will cheat you."

Text box continued on page 24

cannot be depended on in all situations. The most reliable and useful software that I have purchased runs under a standard operating system and is easily modifiable by means of a configuration program or a copy of the source code.

More than once, I have decided not to purchase a desirable software product when I became aware that it did not support our system configuration and was packaged in a copy-protected form. Surely the revenue lost to vendors in this manner is as significant as that lost to "pirates."

Our firm plans to enter the small-computer-software market through direct and retail sales. BYTE readers should be assured that our programs will be fully accessible, modifiable, and packaged with source code whenever feasible.

Yes—we'll be vulnerable to piracy. But I believe that the solution to the software-piracy problem is increased vendor support (rendering pirated copies less valuable) and vigilant enforcement of protective laws, *not* making software products less accessible to the user.

Michael C Berch
Managing Partner
Southside Systems
2424 Haste St
Suite A-40
Berkeley CA 94704

Text box continued:

There is no sacred bond above which all transactions are honest and below which honesty is negotiated.

I sent away for the software I required to keep writing. As luck would have it, I had been legitimately given two key pieces of software, that were mine to keep, in return for providing reviews to magazines. So as it turned out, I had won and I had lost. Cleaning up my act didn't cost me as much as I thought it would; however, I lost a friend. I consider that loss the highest price to pay for my transgression.

I'm sure there are those who will be critical and demand I pay for the software I used for the two years. All I can say is that I've given it careful thought and I feel comfortable with my current situation.

Foolproof, protected software is fiction and will never be reality because it has nothing to do with technology. It has to do with the human condition. There always will be people who will compromise integrity for material gain. And there will be those, like myself, who will slip past honesty and into what they often call a "gray area" before they get their heads out of the sand and take responsibility for their actions. And, thank God, there are a handful whose integrity will not waiver. As long as this human condition exists, there will be no perfect system for software protection.

There are, perhaps, only two reasons for maintaining personal integrity. One is the fear of being discovered and exposed—or worse, punished. An idea I read a year or so ago suggested that a bounty on pirates may be the most workable tool to enforce this first reason. I don't like this idea: there are too many holes in it. But it does seem the most effective way to put the fear of being caught into pirating.

On the other hand, there is the moral fiber within each of us that merely needs to be awakened to become strong and effective. Careful examination of your situation with a critical eye on what you know to be right and wrong will certainly expose any deficiencies. It then becomes a matter of pricing your integrity and remembering that you can't steal software by yourself. Yes, the process of evaluating the circumstances is simple. The difficulty of implementation will likely be directly proportional to how deeply involved you are in stealing.

Drop me a postcard—anonymously, if you prefer—and let me know your feelings.

Eugene Dorman
c/o BYTE Publications Inc
POB 372
Hancock NH 03449

I would like to comment on the May 1981 BYTE editorial and the two articles on the subject of software piracy. There are two sides of every fence. BYTE took the side of the software provider; let me take the side of the user.

I purchased an Apple II, disk drives, video monitor, printer, modem, etc, plus about $1000 worth of software for business use. This is not my hobby, and I have no intention of becoming any more of an expert with computers than I must to achieve my purpose.

From my standpoint, the price of all of this stuff is so low that there is absolutely no point in messing around either with pirates or in doing it myself. Even the bookkeeping and inventory-control programs, at $600 to $1000 or more, pay for themselves in a few months. If the minicomputer manufacturers could ever get their act together, the business-software market would dwarf their present endeavors. (I think that the Japanese will do the job for them, and Apple will wind up back in the old garage along with the others.)

I have two Apple programs that provide access to the Dow Jones data base for the purpose of obtaining securities quotes, keeping track of portfolios, and the like. One program is written in BASIC, is user-accessible and, with some user modifications, works like a charm. The other program is "locked." It doesn't work.

Apple has a disclaimer in its program manuals absolving them of all responsibility. So far, Apple hasn't abandoned me, but it's taking its own sweet time about coming up with a fix. When and if a fix comes through, no field modification by the user will be possible. I have a pretty good idea what the problem is and if I could gain access to the program, I could probably fix it myself in a short time. This way it will take weeks or months, if it gets fixed at all. I think the denouement is that a determined and knowledgeable pirate will succeed no matter what, while the honest and legitimate user, like me, takes it on the chin.

Adolph L Friedman
POB 2856
Santa Fe NM 87501

I disagree with Chris Morgan's editorial on software piracy. It seems that the software expert has a stranglehold on the personal computer. His hand is clutched around my wallet and he is squeezing for all it is worth. I don't like that. In the capitalistic system, competition brings the price in line. Software is a monopoly, and Mr Morgan's concern is like government-secured loans to Chrysler.

Why not let the software people provide more flexibility to the user? If the software is easier to obtain and more reasonably priced, a larger number of people would own personal computers.

Most small system users think all microcomputers are created equal. And they're right. If you want performance, convenience, styling, high technology and reliability (and who doesn't?) your micro usually has a price tag that looks more like a mini. It seems big performance always means big bucks. But not so with the SuperBrain!

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That in itself would increase the market for software. The broader the base of people using computers, the greater the variations and the need for software.

What Mr Morgan proposes is like Exxon buying up the "good gas-mileage carburetors" before they get to market. It sounds to me that Mr Morgan is trying to protect the pirates.

Brigg Leurs
436 N 1050 E
Kaysville UT 84037

It seems to me that the solution to software piracy has been evident and used for a considerable time by BYTE's parent company, McGraw-Hill. Hundreds of man-hours can be used in the writing and debugging of a program, and this can be translated into cost and selling price, the same as any other commodity.

The Osborne Accounting System, for example, has a finite value. The disks for each program are available at a very low price, even as low as $8, from one of BYTE's advertisers. However, the comprehensive and beautifully published manuals that include the source code can be purchased for $20. You could not photostat one of these manuals for less than this price. Therefore, you buy it.

It would be interesting to know how many manuals the McGraw-Hill Book Company has sold and what the income has been, per program. I'm sure this shows one solution: give the disk away and sell the manuals, like the old stunt of giving the razor away, but selling the blades. All of the methods for "locking in" programs and "locking out" software pirates are rather foolish. Everyone knows that you can access every byte on every track, change the ID and password, disassemble, and transfer from one system to another.

A A Schwartz
6454 El Camino Del Teatro
La Jolla CA 92037

The antipiracy devices mentioned in Chris Morgan's editorial are quite ingenious, but like all human inventions, they are fallible. I wonder if BYTE readers would like to reconsider the whole question of "software protectionism" at a more elementary level.

I can identify at least three basic "instincts" at work which must be accommodated:

- the natural inquisitiveness of the human mind
- the insatiable attraction of acquiring things for oneself
- and the irresistible challenge of another human mind

Inasmuch as knowledge and information are the essential contents of all software, to keep them "locked away" is old-fashioned logic. Widely disseminated knowledge will bring forth more knowledge. In an age when knowledge becomes rapidly outdated, hanging on to some little invention is unrealistic. Like all attempts at prohibition, the setting up of barriers is probably the most potent stimulus to overcome them. Such attempts have only resulted in the escalation of costs to the consumer, the production of weird and delicate formats that are much more prone to crashes, and the great step backward of adding unnecessary keys and ROMs (read-only memories) that defeat the advantage of computerization.

Is it too late to take a 180° turn and stop this "cold war" from escalating? Would it be possible to take the alternate view? Here are some suggestions:

- The ultimate way of getting rid of piracy is to make the purchase of genuine software so cheap that it becomes uneconomical to copy. Who bothers photocopying paperback books? The volume of sales will more than compensate for the lowering of the profit margin and protection costs.
- Software houses should encourage users to become subscribing members. This would provide capital for software development as well as some degree of customization of the software to be developed. New programs could be offered to subscribers on a priority discount basis.
- Users clubs should be encouraged to adopt a code of ethics; in return they would be allowed to participate in a scheme of evaluation and bulk ordering of new products. There is no pressure greater than peer pressure.
- A good user and upgrading service should be arranged so that a firm bond is created between the user and the software producer. Newsletters with user comments is one way to achieve this.

I am glad to say that at least one software company, Personal Software, has begun to adopt this new attitude for its Data Management System and Desktop Plan. I salute them. I sincerely hope that BYTE and its readers will take the initiative of spearheading this more rational approach before you have to say "open sesame" to your computer.

Dr A Hua
Department of Medicine
Queen Mary Hospital
University of Hong Kong
Hong Kong

Letters continued on page 30

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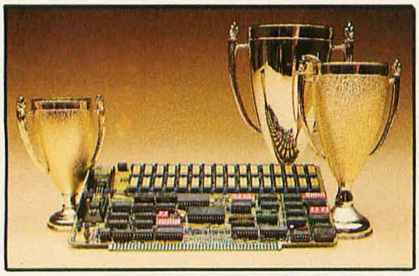

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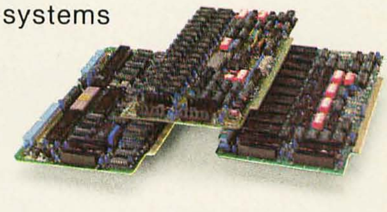

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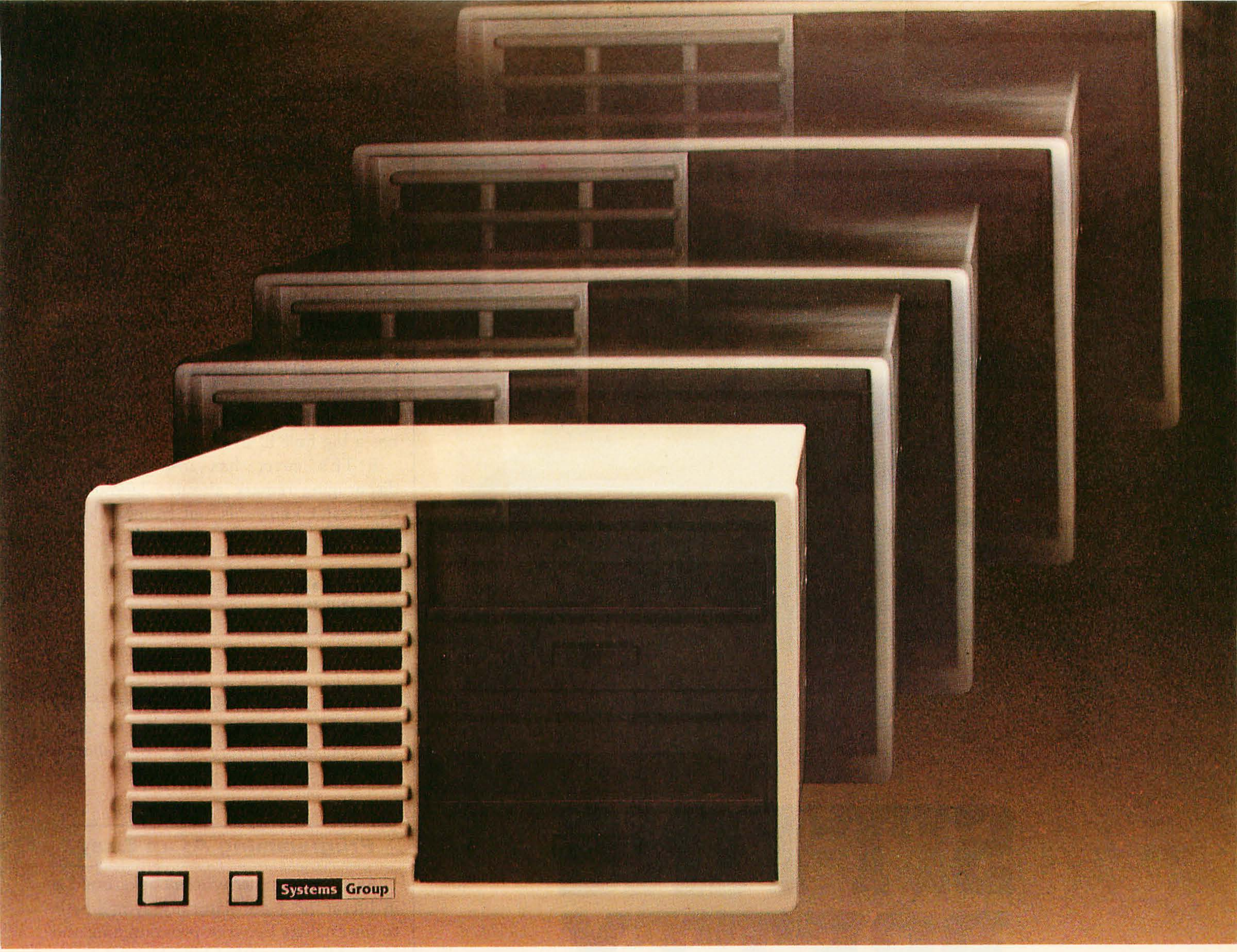

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Letters

The Wind Blowest Where It Listeth

Something is a bit strange about BYTE's May 1981 cover. The sail is full and set for a run (which means wind astern), the burgee points to port (which means wind off the starboard), and the spray from the bow wave points to starboard (which means wind to port). I've seen things like this on a lake just leeward of an island, but only for a moment. It's pretty unlikely on the open sea. And, worst of all, the sail has a big hole in it!

BYTE's cover has inspired a new disparaging remark about a landlubber: he doesn't know his sail from a floppy disk.

John A Ball
Oak Hill Rd
Harvard MA 01451

The May cover is a faithful representation of a situation that occurred during the BYTE staff's last outing. By the way, we know about floppy disks, but what's a "sail"? . . . CPF

Programming As an Essay

As a programmer whose background is in literature, I am naturally sympathetic to the analogy between programming and natural languages that John Handel draws in his article "The New Literacy: Programming Languages as Languages." (See the March 1981 BYTE, page 300.) That a programming language is indeed called a language, that programming borrows much of its lingual terminology from natural languages (eg: word, paragraph, syntax), offers at least a hint of the parallel that Mr Handel persuasively develops.

At one point, however, he makes an analogy between a program and a book that I find a bit contrived. His argument would be better served with an analogy between a program and a formal essay. Having written both, I find the thought processes involved in both remarkably similar.

Essentially, a formal essay consists of a thesis, arguments to support that thesis, and a conclusion. Its usual purpose is to interpret, persuade, or inform: to solve some critical or rhetorical problem. Before writing can begin, an essayist must be able to express clearly to him- or herself the thesis and conclusion in order to define

the problem, its scope, and to provide a framework for its solution. Similarly, a programmer must have a definition of his or her problem, and he or she must be able to frame a solution before coding can begin. Both the essayist and the programmer must know where they want to go before they can begin the detailed work to get there.

Next, the essayist must gather his or her major arguments and break the thesis into components, just as a programmer will break the problem into manageable parts. A writer will then arrange the arguments so that they flow smoothly through the essay. A programmer will begin arranging the parts of the problem so that they operate in an orderly fashion.

Finally, the detail work can begin. A writer will supply minor arguments and examples to "flesh out" his or her work. A programmer at this point concentrates on code. Both will polish their work, ensuring that grammar, diction, and syntax are correct.

An essay may not have to communicate "in a precise fashion" and an essayist must rely on a reader to "test" the thesis (not as strict a standard as a programmer's computer), but an essay must communicate in a reasoned and orderly fashion. Both writer and programmer must be logical within a verbal framework.

I agree with Mr Handel's conclusion that a programmer with verbal sensibility will tend to write readable programs that work. Perhaps then, programming installations, especially commercial shops where the work is not technical or mathematical, may do well to employ language and linguistic students. Perhaps too, a source of programming talent may be found in writers and students of philosophy and history who already have a command of language and procedural skill and who could learn the particulars of programming quickly and easily.

Michael J Nichols
1725 York Ave
New York NY 10028

Vikings Defense

It may be that BYTE's attention somehow has been focused on the aspects of violence in the history of the Vikings. The cover on the May 1981 BYTE and the text on page 4 does, however, indicate that BYTE ought to read up on the Vikings as well as on their contemporary history.

BYTE has done the Vikings a gross injustice by merely stating that they were "notorious pirates." Let me say in their defense that they were also clever sailors, innovative navigators, explorers, and tradesmen, who traveled routes that today seem impossible considering the equipment they had at hand. They were tough, maybe, and violent—living in times of different general ethics and values than you may wish for yourself today. But, to call them pirates, with an indication of lawlessness, is simply an (unfair) application of current values to a very different time and place.

The Vikings also were clever shipbuilders, building perhaps the most beautiful boats that have ever been made. You may see some of these here in Oslo and judge for yourself.

Einar Skjørten
Rytterfaret 21
1347 Hosle, Norway

We apologize, Mr Skjørten, for our somewhat simplistic representation of the Vikings. . . . **CM■**

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Book Reviews

Principles of Artificial Intelligence

Nils J Nilsson
Tioga Publishing, 1980
476 pages, hardcover
$27.50

Reviewed by
Steven K Roberts and
James Paul Jenal
5885 Dublin Rd
Dublin OH 43017

Artificial intelligence (AI), for over two decades the arcane province of academic visionaries, is at last spilling over into the worlds of engineering and practical system design. A fascination with the programming language LISP is sweeping the industry, robotics and machine vision (though still primitive) are something other than fantasy, and the cost of computer hardware on a scale necessary for AI work has dropped to the point where it even touches the personal computer spectrum.

It is becoming worthwhile to learn something about the subject for reasons beyond intellectual curiosity.

A new book by Nils J Nilsson offers a substantive look at a body of techniques upon which much of the work in the artificial intelligence field is based. Presently the director of the Artificial Intelligence Center of Stanford Research Institute, Nilsson has for years been involved in problem-solving, theorem-proving, and planning systems, and has authored publications along these lines that date back to the early 1960s.

Principles of Artificial Intelligence is intended as a text for a college senior or first-year graduate student, and can thus be considered to be the reader's first serious exposure to the field. But a question arises as to whether or not the ensuing (fairly rigorous) discussion of predicate calculus is the way to proceed. Though the text was written as an introduction and does, in fact, concern itself far more with underlying techniques than with applications areas, it focuses fairly strongly upon formalisms with which the reader new to the field might be a little uncomfortable.

Predicate calculus is certainly not new to serious students of computer science—it is required material in almost any undergraduate computer-science curriculum, though exposure is typically limited to formal proving exercises. Nevertheless, predicate calculus does provide a refined set of manipulative tools that are useful for the implementation of knowledge-based production systems, and it has a distinct advantage over some of the more intuitive paradigms, such as relational databases and semantic networks, in that it has matured from many years of disciplined development in other application areas. Though imposing in appearance, it is a reliable basis for system design and, thanks to its universal acceptance, for communication of ideas with other workers in the field.

However, one of the ideals of artificial intelligence work is the comfortable bridging of the vast conceptual gap between man and machine. Although this inevitably requires the application of formal tools, it should eventually lead to increased "naturalness" of problem expression. In a purely rigorous sense, any Turing machine implementation is as good as another (they provide the same computing power), but the differences to those who must use them are significant. As anyone who has ever attempted to express abstract, symbolic constructs within the syntactical and semantic restrictions of FORTRAN knows only too well, the issue of naturalness is inexorably tied to the *representation* problem.

Early on, Nilsson states that "selecting a good representation is one of the important arts involved in applying AI techniques to practical problems." This is indeed true, not only in this field but in all aspects of computer problem solving. Knowledge representation, whether via a body of production rules (if...then constructs), frames (relatively passive data entities appropriately interconnected and applied to a set of inference procedures), or any other means, is a central and hotly contested issue that affects not only the usefulness of a system's design but its naturalness. While different approaches may not necessarily provide greater power, they might free the mind to achieve greater insights—and insight is at the heart of all problem solving.

Nilsson makes a good case for the use of predicate calculus as the set of "cranks" with which any type of system can be implemented. Whether or not this approach constitutes an optimal entry into the artificial intelligence field is partly a function of the reader. From a classical engineering standpoint, the assimilation of formal methods before exposure to the more philosophical aspects is absolutely necessary, and for those who are comfortable with this approach, the book comes highly recommended: the problems are interesting, yet not so esoteric that you lose sight of their purpose—namely, the chance to apply the principles that Nilsson has so painstakingly laid out. Those who lack the text's presupposed ease with formal methods (and there is much of interest in the field that does not require it) might prefer a book targeted to an overview of AI's various subspecialties (such as Patrick H Winston's classic, *Artificial Intelligence*, Philip C Jackson's *Introduction to Artificial Intelligence*, or Pamela McCorduck's *Machines Who Think*).

Principles of Artificial Intelligence, like its predecessor, *Problem-Solving Methods in Artificial Intelligence* (Nilsson, McGraw-Hill, 1971), can be considered an authoritative text on many of the underlying ideas that serve as the basis for the bulk of current artificial intelligence research. After Nilsson develops the primary theme, he provides a number of provocative comments about the field, and closes with a comprehensive and up-to-date bibliography of published works. Though hardly casual reading, the book offers solid underpinnings for methodologies which might otherwise appear disquietingly magical.■

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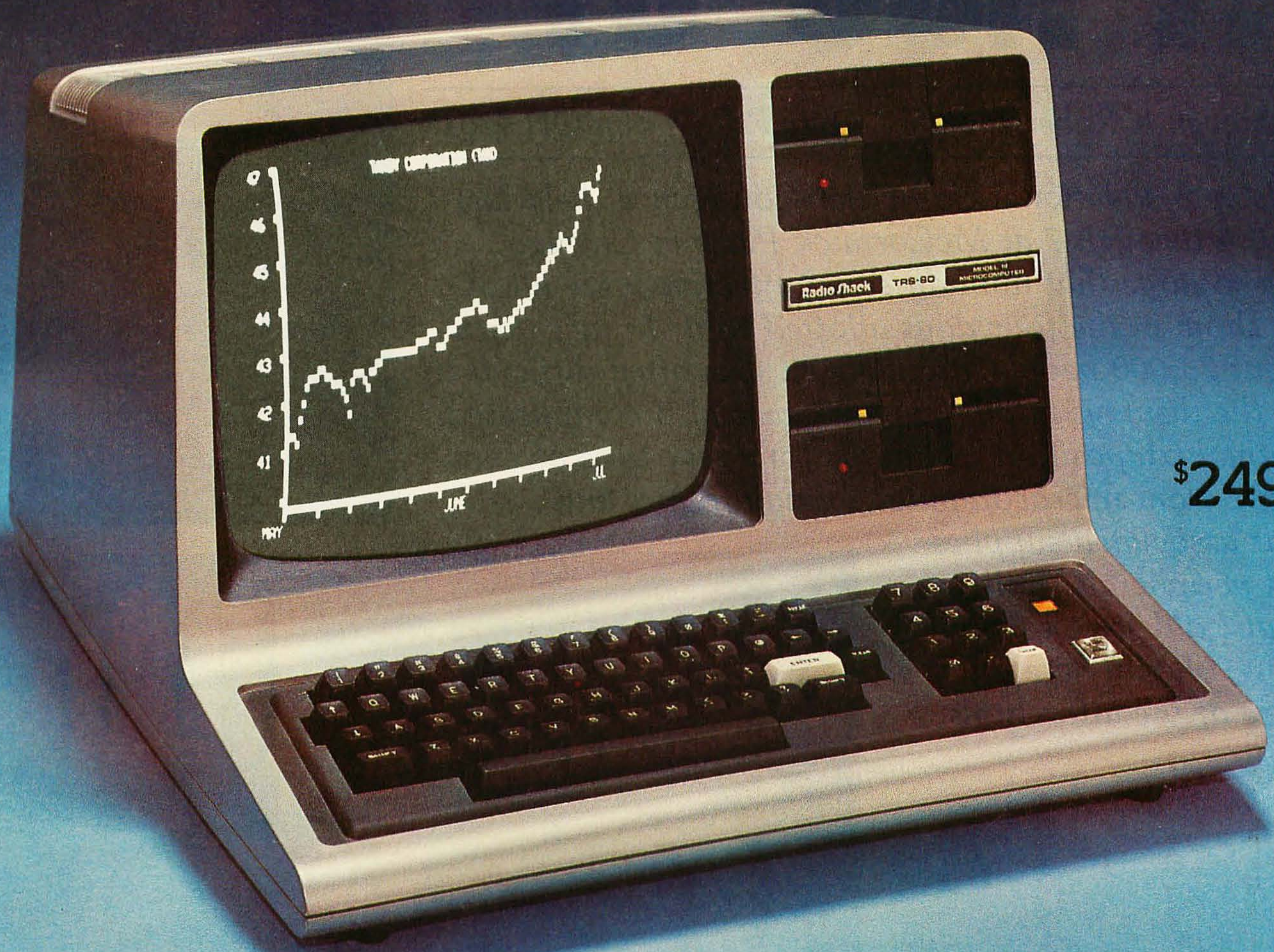

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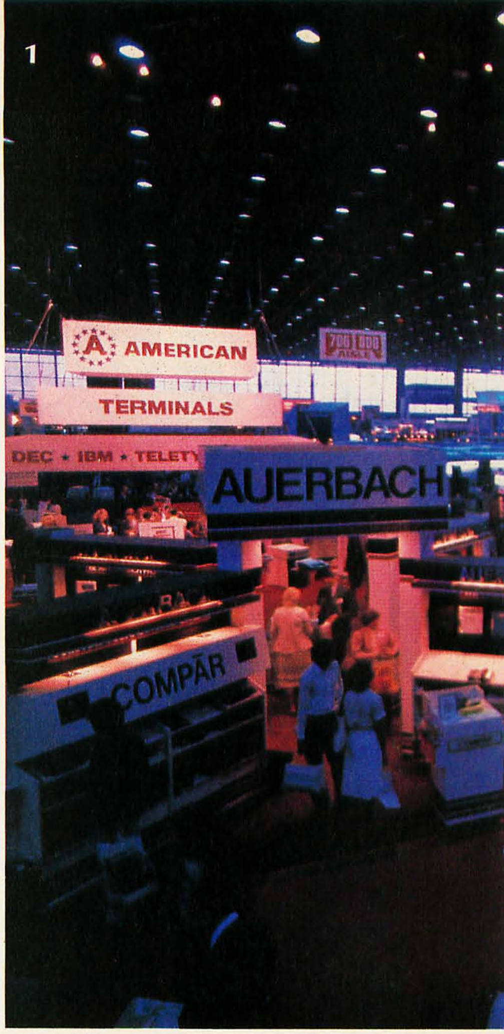
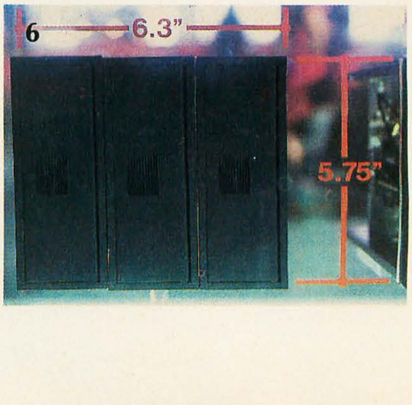
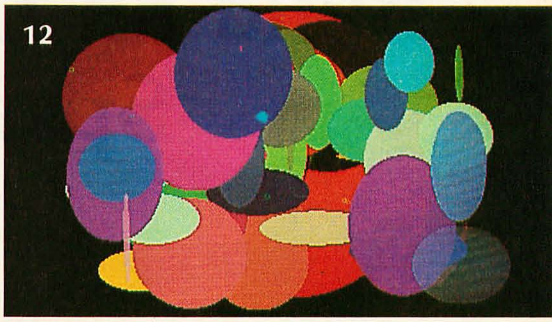
A LOOK AT NCC '81

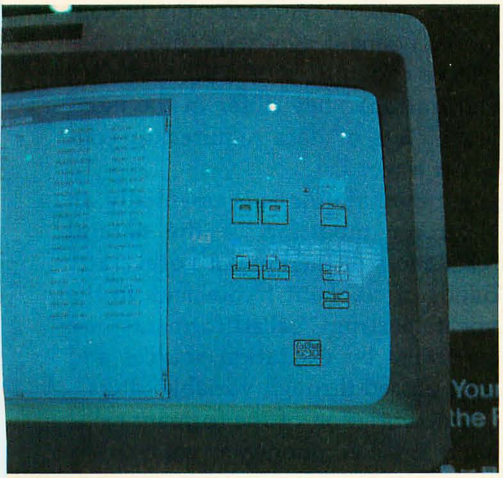
by Steven K Roberts, 5885 Dublin Rd, Dublin OH 43017

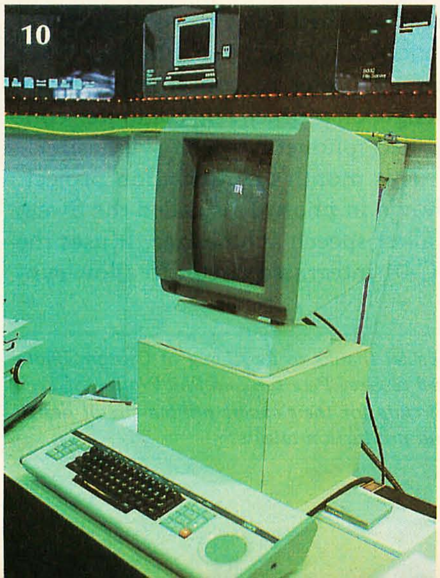
This year's National Computer Conference, held last May 4 through 7 at McCormick Place in Chicago, was so large that nobody could effectively see all of the show in the four days allotted to it. In fact, with about 73,000 people attending, it was often difficult to see the displays at all. The task was also complicated by the juxtaposition of booths for every type of computer, from microcomputer to mainframe, and their associated supplies and peripherals. Still, what I did see was exciting; shown here are some of the attractions.











1 *Any attempt to capture the entire NCC in a single photograph is doomed to failure.*
2 *The BMC IF-800 microcomputer. This new entry from Japan is impressive, although its price might be too high for the casual user.*
3 *The LEX-21 is a portable terminal with a full-size keyboard, a 40-column printer, a buffer of up to 8 K bytes of memory, and a built-in direct-connect 300-baud modem.*
4 *The Apple booth was constantly well attended because of the many applications being demonstrated.*
5 *The Corvus Omninet, a local network system that can interconnect up to 64 microcomputers via a simple twisted-pair wire connection. Each microcomputer connects to the twisted-pair bus through an interface called a "transporter." Interfaces now exist for Apple, LSI-11, and Onyx computers.*
6 *BASF's slimline 5.25-inch floppy-disk drives. Three of these units will fit in the space of two drives of conventional design.*
7 *The TRS-80 Color Computer was displayed prominently at the Radio Shack booth. With its Extended Color BASIC, the unit can deliver impressive color graphics.*
8 and **10** *The Xerox Star. A view of the unit's video display, photo 8, shows why the Star was one of the most popular exhibits at the show—it delivers on its promise of "What you see on-screen is what you get." Photo 10 shows the Star itself, an intelligent office terminal that can be connected to Xerox's Ethernet.*
9 *The Sony Typecorder, a self-contained, battery-powered "portable office" about the size of an issue of BYTE. The unit stores both voice and text (up to 120 pages) on a microcassette and can dump text to a printer or transmit it over telephone lines.*
11 *Tandon displayed an 8-inch floppy-disk drive that is exactly half the width of conventional units.*
12 *A high-resolution display using Cromemco's Super Dazzler board along with its SDI color-graphics interface. The resulting video image can be made from a palette of 2048 colors.*

Build an Unlimited-Vocabulary Speech Synthesizer

Steve Ciarcia
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Glastonbury CT 06033

The alarm clock that jolts you out of sweet dreams with a monotone buzz is a thing of the past. State-of-the-art technology is the clock that prods you out of slumber with a *voice* that speaks your own language: "The time is 6 o'clock."

The artificial voice is becoming an increasingly important and potentially indispensable part of the interface between man and machine. Electronic speech synthesis is a young but rapidly evolving technology. It won't be long before that speaking alarm clock will also announce your entire day's appointment schedule. It will be no less unusual for the computer in your car to recount its mechanical ills as you drive to work. For now, however, electronic speech synthesis is still a relatively new concept.

In a previous Circuit Cellar article ("Build a Low-Cost Speech-Synthesizer Interface," June 1981 BYTE, page 46), I described the design of an inexpensive, limited-vocabulary, computer-controlled electronic speech synthesizer called the Micromouth. This speech processor, based on the National Semiconductor Digitalker chip set, was an attempt to introduce personal computer users to artificial speech. Considering the response it received, I believe many of you are now listening to everything your computer has to say.

This month I wish to return to the topic of computer-controlled electronic voice synthesis and introduce you to the Votrax SC-01 speech synthesizer chip.

Instead of waveform digitization or linear-predictive coding, the SC-01 uses phoneme synthesis, which allows the SC-01 to speak an unlimited vocabulary simply by sequentially pronouncing the individual phonemes (basic sound units) that make up words in the English language.

Many other articles have been written that describe in detail the theory of phoneme synthesis and the workings of the Votrax SC-01 integrated circuit. A few appropriate references are given at the end of this article. Instead of discussing many theoretical concepts at length in my limited space here, I prefer to concentrate on the design of a practical, computer-controlled, phonetic speech synthesizer.

This month's construction project, shown in photo 1, is called the Sweet Talker speech synthesizer. It uses the SC-01 integrated circuit to allow synthesis of an almost unlimited vocabulary (limited only by the size and complexity of the controlling program running on the computer). The Sweet Talker circuit contains I/O (input/output) signal buffering, a clock oscillator, an audio filter, and an amplifier. The circuit board provides protection from static electricity for the SC-01 in addition to being a convenient package. (Protection for the SC-01 is important, because it is both expensive—$70—and delicate. It's made using complementary metal-oxide semiconductor technology.) The standard Sweet Talker synthesizer can be connected to any microcomputer through a parallel port, while a special version of the unit can be plugged into the I/O bus of the Apple II computer.

Speech-Synthesis Review

Three major techniques are presently used to synthesize the human voice: formant synthesis, linear-predictive coding (LPC), and waveform digitization. They differ in the number of bits of data required to construct a word.

Formant synthesis is essentially an electronic modeling of the natural resonances of the human vocal tract. Bands of resonant frequencies in the vocal spectrum, called formants, are generated by excitation sources and then passed through variable filters.

One variation of the formant technique is called phoneme synthesis, in

Votrax is a trademark of Federal Screw Works, Inc.

Digitalker is a trademark of National Semiconductor Corporation.

Special thanks to Ray Long of Custom Photo and to Greg Peterson and Phil Walton of Tech Circuits for their expert printed-circuit design and production talents.

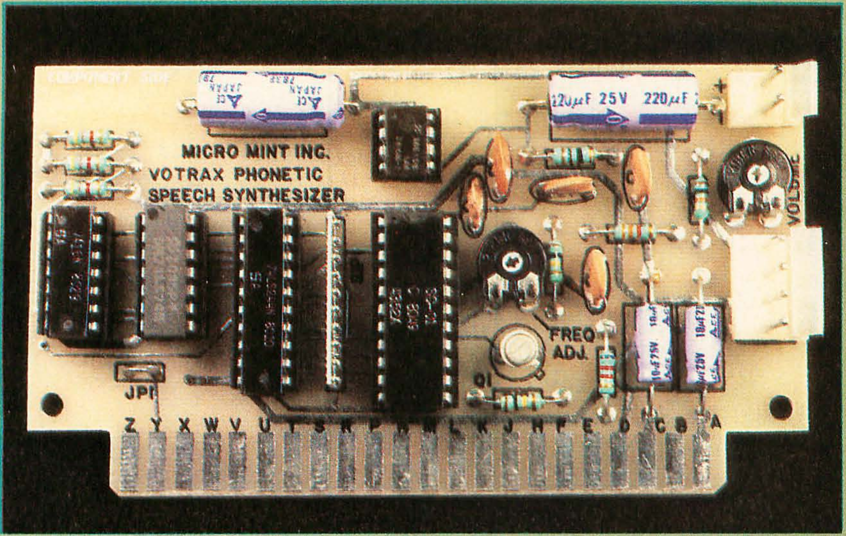


Photo 1: *The assembled Sweet Talker phonetic-speech-synthesizer circuit board. The Votrax SC-01 phoneme-synthesizer integrated circuit supports a vocabulary limited only by the size and complexity of the computer program that controls the Sweet Talker. Any English word may be constructed from phonemes, the basic building blocks of speech. The circuit board shown is a prototype of the parallel-port version of the Sweet Talker; the Apple II plug-compatible version is not shown.*

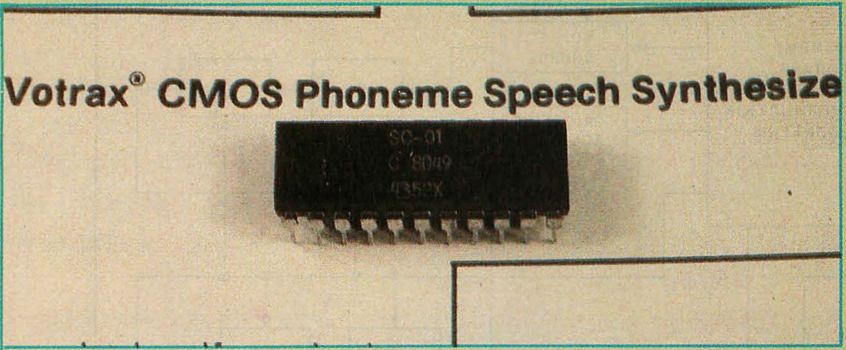


Photo 2: *The Votrax SC-01 is a 22-pin CMOS integrated circuit which functions as an electronic model of the human voice.*

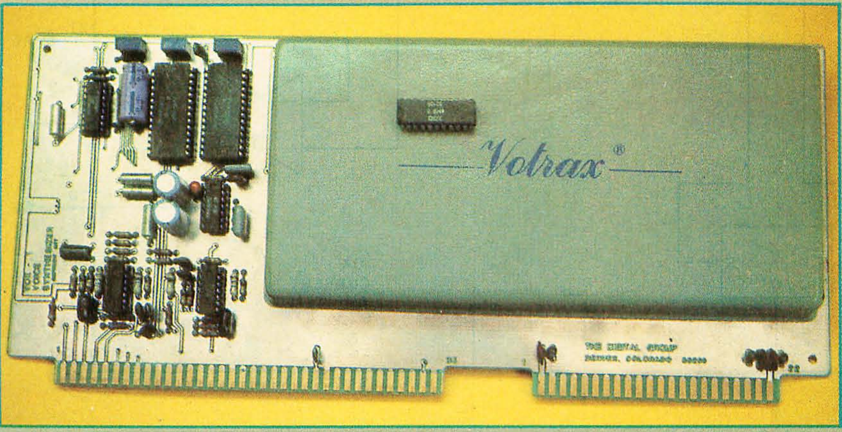


Photo 3: *Before the development of the SC-01, Votrax used many medium-scale-integrated circuits and discrete components to perform the same functions. All these components were mounted in modules such as the VSL-type shown. When this particular synthesizer card was purchased three years ago, the price was $600. Compare this both in size and price to the $70 SC-01 (sitting on top).*

which the spectral parameters are derived from basic sound units that make up words. A phoneme-generator circuit is used to reproduce these sounds. In such a circuit, each phoneme is given a numeric code, and the synthesizer circuit (discrete or integrated) utters phoneme sounds corresponding to codes it receives when it is activated. Words and sentences are assembled by simply stringing the phoneme codes together. The electronic voice so generated is intelligible, but has a slight mechanical quality. Continuous speech using phoneme synthesis can typically be generated with a data rate of less than 100 bps (bits per second).

Linear-predictive coding is similar to formant synthesis in that both techniques are based in the frequency domain and use similar hardware to model the vocal tract. The quality of speech is often better than formant or phoneme synthesis, but a higher data rate (1200 to 2400 bps) is needed for continuous speech.

Waveform digitization is the third method of speech synthesis, in which the amplitude characteristics of a vocal waveform are stored and reproduced. The quality of speech is better than the other two methods, but the data rate for continuous speech is very high, and storing sufficient amounts of data conveniently can be a problem. Various schemes of compressing the data have been devised; one of the more successful is used in the National Semiconductor Digitalker system, which I described in my June Circuit Cellar article.

Votrax SC-01

The 22-pin Votrax SC-01 integrated circuit, shown in photo 2 and in the diagrams in figure 1, contains a digital code translator, or phoneme controller, and an electronic analog of the human vocal tract. The phoneme controller translates a 6-bit phoneme code and a 2-bit pitch code into a matrix of spectral parameters which in turn adjusts the vocal-tract analog to synthesize the phonemes.

In the first part of the vocal-tract section, there are a pair of variable-frequency oscillators for simulating

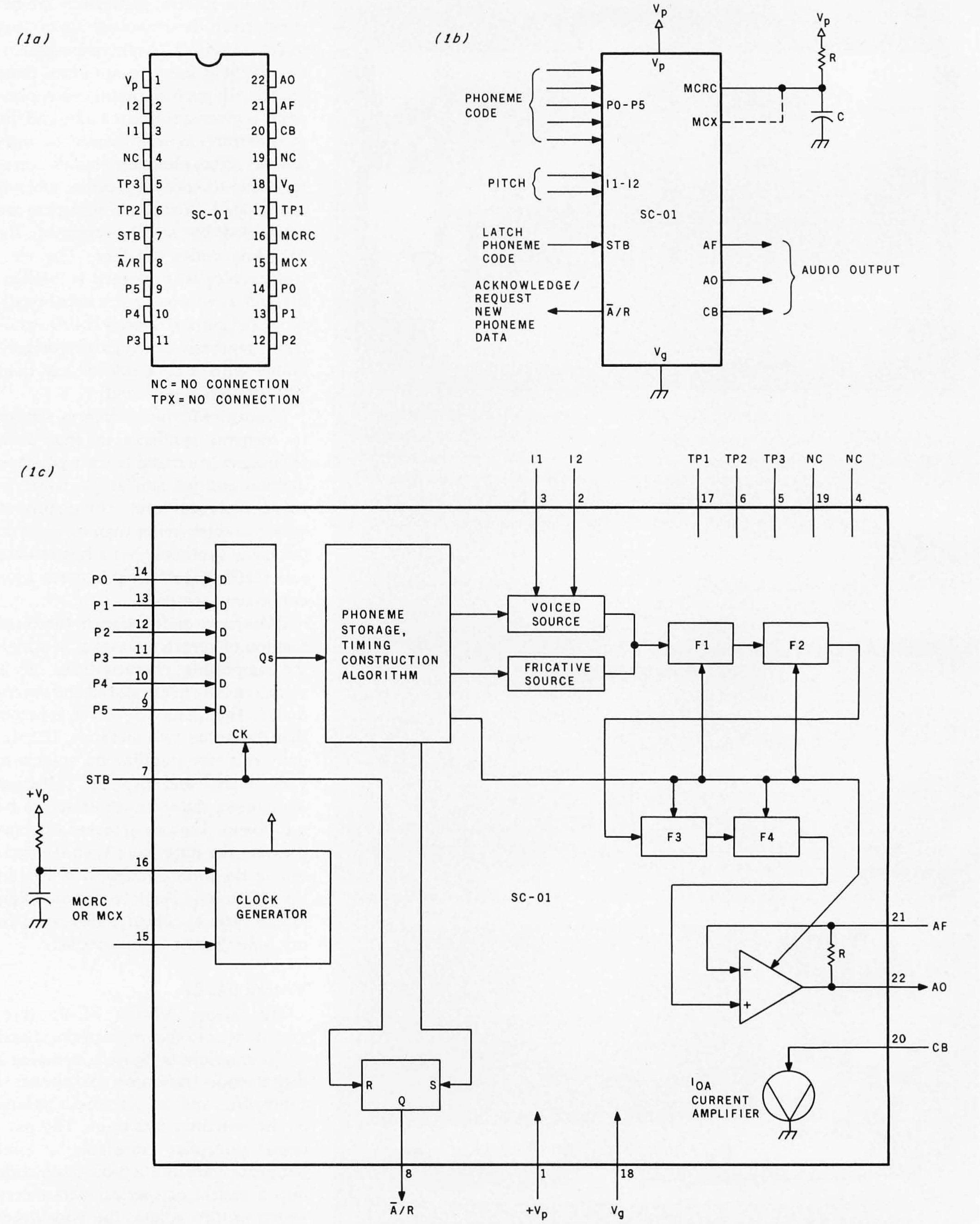


Figure 1: *Technical characteristics of the Votrax SC-01 Speech Synthesizer Chip. Shown are the pinout designations (1a), the scheme of data flow through the circuit (1b), and a block diagram of the internal structure (1c). This figure is reproduced courtesy of the Votrax Division of Federal Screw Works, Inc.*

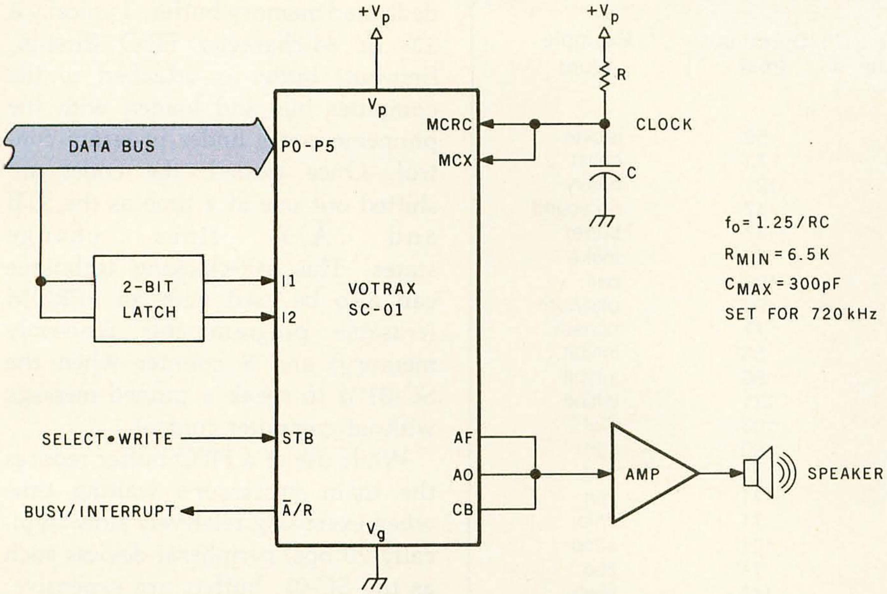


Figure 2: *A diagram of the general connection scheme of the SC-01.*

vocal-cord-produced periodic sounds and a pseudorandom (pink-noise) signal generator that simulates the sound of rushing air. The output signals from these sources are shaped by a bank of four analog band-pass filters that simulate the vocal-tract cavities. The filter outputs, in turn, are directed through a preamplifier to an external amplifier and speaker.

The SC-01 phoneme synthesizer is a CMOS (complementary metal-oxide semiconductor) integrated circuit which should be operated within the range of 7 to 14 V (V_p). The phoneme-input lines (P0 through P5) are 5 V level-compatible and self-latching. (Here "5 V level-compatible" means matching LSTTL [low-power Schottky transistor-transistor logic] levels with an *external* pull-up resistor.) The two pitch-control lines, on the other hand, must have external latches and must be switched at the same input voltage as the SC-01's power supply. Handshaking with external control circuitry is accomplished through two control lines: strobe (STB) and acknowledge/request ($\overline{A}$/R). The STB line can be either CMOS or 5 V level, while the $\overline{A}$/R line is CMOS level only.

The output pitch of the phonemes is controlled by the frequency of the clock signal, which can be applied from an external source or set internally with a resistor and capacitor combination. The clock frequency is nominally 720 kHz, but subtle variations of pitch are induced through "automatic inflection" to prevent the synthesized voice from sounding too monotonous or "robot-like." Two independent pitch-control lines, I1 and I2, are available for gross variations in pitch so that the chip can speak with more than one voice. Referred to as "manual inflection" controls, I1 and I2 operate in addition to the automatic-inflection system already present. I have found that the 6-bit phoneme code alone is sufficient, and the two pitch-control lines can be ignored. A diagram of the general connection scheme is shown in figure 2.

Listed in table 1 on page 42 are the 64 phonemes defined for the English language (two produce silent periods of different lengths; one causes synthesis to stop). A phoneme sound is generated when a 6-bit phoneme code is placed on the control-register input lines (P0 through P5) and latched by pulsing the strobe (STB) input. Each phoneme is internally timed and has a duration of 47 to 250 ms (milliseconds); some phonemes last longer than others, and variations in the clock frequency affect the phoneme durations. The $\overline{A}$/R line goes from a logic 1 to a logic 0 when a phoneme is sounding.

There are two general methods for using the SC-01. One method, shown in figure 3a on page 43, configures the chip in an independently acting, self-timed circuit which asynchronously extracts phoneme codes from a

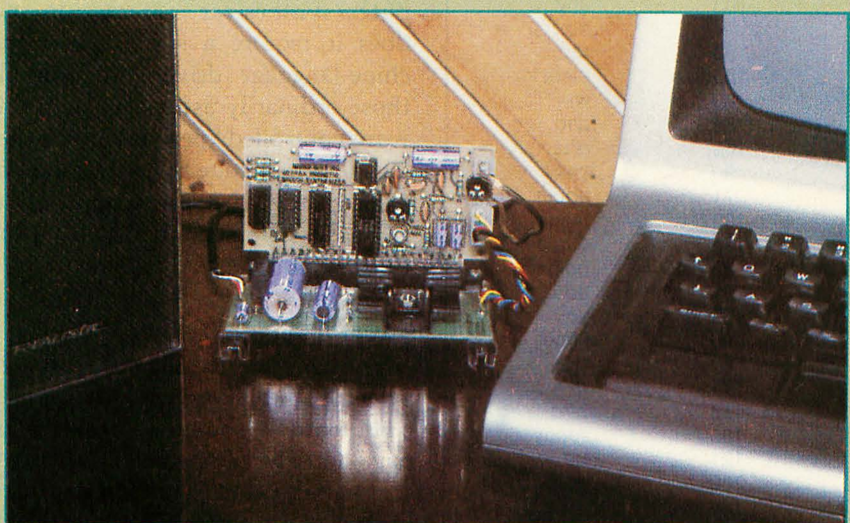


Photo 4: *The Sweet Talker phonetic-speech-synthesizer board can be driven through any parallel output port. One port which can be used is a Centronics-compatible parallel printer port. When using this connection, phonemes for words to be spoken are transmitted using LPRINT statements in BASIC. Pictured above is the Sweet Talker board combined with its power supply and connected to a TRS-80 Model III computer and a speaker.*

Hexadecimal Phoneme Code	Phoneme Symbol	ASCII Character	Duration (ms)	Example Word
00	EH3	@	59	jacket
01	EH2	A	71	enlist
02	EH1	B	121	heavy
03	PA0	C	47	no sound
04	DT	D	47	butter
05	A2	E	71	make
06	A1	F	103	pail
07	ZH	G	90	pleasure
08	AH2	H	71	honest
09	I3	I	55	inhibit
0A	I2	J	80	inhibit
0B	I1	K	121	inhibit
0C	M	L	103	mat
0D	N	M	80	sun
0E	B	N	71	bag
0F	V	O	71	van
10	CH	P	71	chip
11	SH	Q	121	shop
12	Z	R	71	zoo
13	AW1	S	146	lawful
14	NG	T	121	thing
15	AH1	U	146	father
16	OO1	V	103	looking
17	OO	W	185	book
18	L	X	103	land
19	K	Y	80	trick
1A	J	Z	47	judge
1B	H	[	71	hello
1C	G	\	71	get
1D	F	]	103	fast
1E	D	↑	55	paid
1F	S	←	90	pass
20	A	(space)	185	tame
21	AY	!	65	jade
22	Y1	"	80	yard
23	UH3	#	47	mission
24	AH	$	250	mop
25	P	%	103	past
26	O	&	185	cold
27	I	'	185	pin
28	U	(	185	move
29	Y	)	103	any
2A	T	*	71	tap
2B	R	+	90	red
2C	E	,	185	meet
2D	W	−	80	win
2E	AE	.	185	dad
2F	AE1	/	103	after
30	AW2	0	90	salty
31	UH2	1	71	about
32	UH1	2	103	uncle
33	UH	3	185	cup
34	O2	4	80	bold
35	O1	5	121	aboard
36	IU	6	59	you
37	U1	7	90	June
38	THV	8	80	the
39	TH	9	71	thin
3A	ER	:	146	bird
3B	EH	;	185	ready
3C	E1	<	121	be
3D	AW	=	250	call
3E	PA1	>	185	no sound
3F	STOP	?	47	no sound

Note: T must precede CH to produce "CH" sound.
D must precede J to produce "J" sound.

Table 1: *The sixty-four phonemes defined for the English language. Two of these produce silence; one causes synthesis to cease.*

dedicated memory buffer. Typically a 32- or 64-character FIFO (first-in, first-out) buffer is attached to the computer bus and loaded with the phoneme codes under program control. Once loaded, the codes are shifted out one at a time as the STB and $\overline{A}$/R lines change states. This self-clocking technique can also be used with an EPROM (erasable programmable read-only memory) and a counter when the SC-01 is to speak a canned message without computer control.

While use of a FIFO buffer reduces the main processor's waiting time when exercising relatively slow (typically 70 bps) peripheral devices such as the SC-01, buffers are expensive. Interface-hardware costs can be measurably reduced by a second scheme: using the computer system (running an appropriate program) to time the transmission of phoneme codes to the SC-01, as outlined in figure 3b. This method sends codes to the synthesizer chip through a latched parallel output port and monitors the synthesizer's activities (via the $\overline{A}$/R line) through an input port or interrupt line.

The latter is the technique I chose to use in my design. Interestingly enough, eliminating the extra hardware doesn't really complicate computer/synthesizer interaction nor does it require a sophisticated machine-language driver program like those ordinarily associated with software-controlled peripheral devices. The program code to control the synthesizer can be as simple as an LPRINT statement in BASIC. More on this later.

Sweet Talker

The schematic diagram of the Sweet Talker speech-synthesizer circuit board is shown in figure 4 on page 44. The phoneme-code bits are sent in parallel to the SC-01 (IC3) and buffered through IC1 (a 74LS244 three-state octal buffer). Pull-up resistors assure that a logic-1 input to the SC-01 will be at least 4 V as required. Unless the board is being used with external address circuitry, the $\overline{\text{Enable}}$ input line (on connector J1,

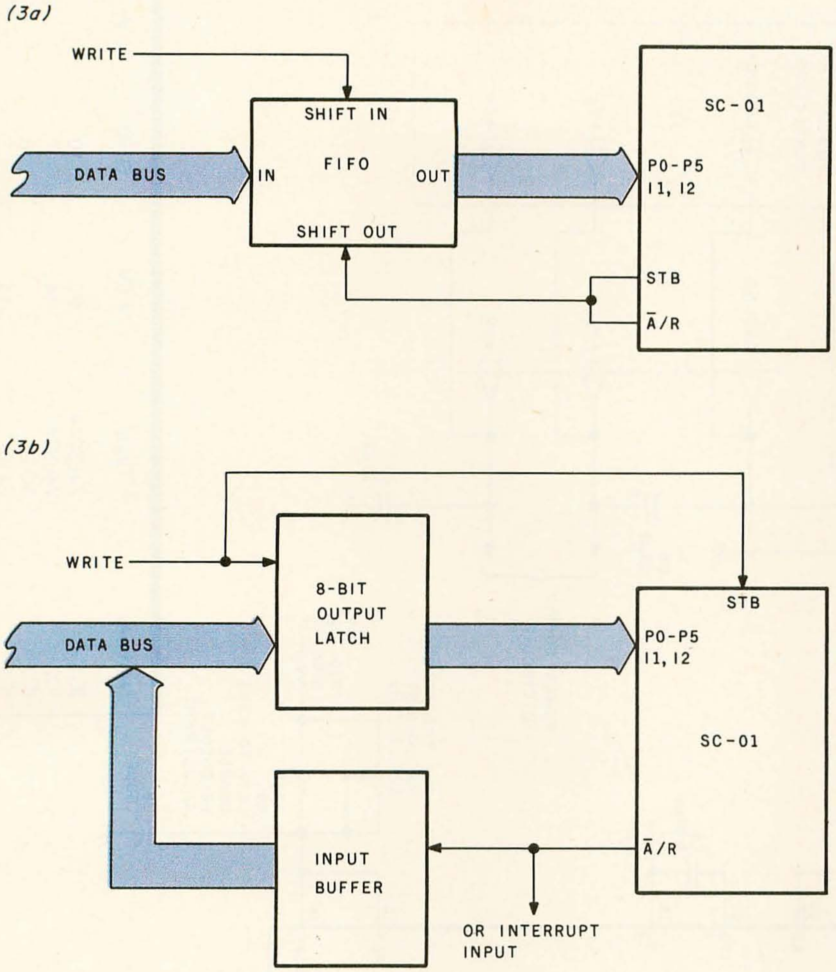


Figure 3: *Two methods of interfacing the SC-01 to a microcomputer data bus. Figure 3a shows an independently acting, self-timed circuit with a FIFO (first-in, first-out) buffer. Figure 3b shows a circuit that allows the computer to time the transmission of data to the SC-01.*

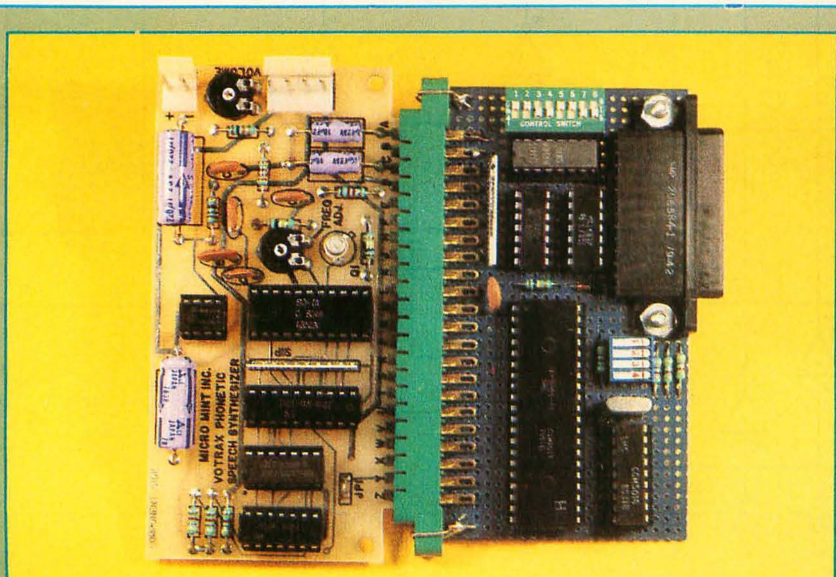


Photo 5: *Many computers have serial, rather than parallel, I/O ports. With a little extra hardware, it is possible to add a serial interface to the Sweet Talker.*

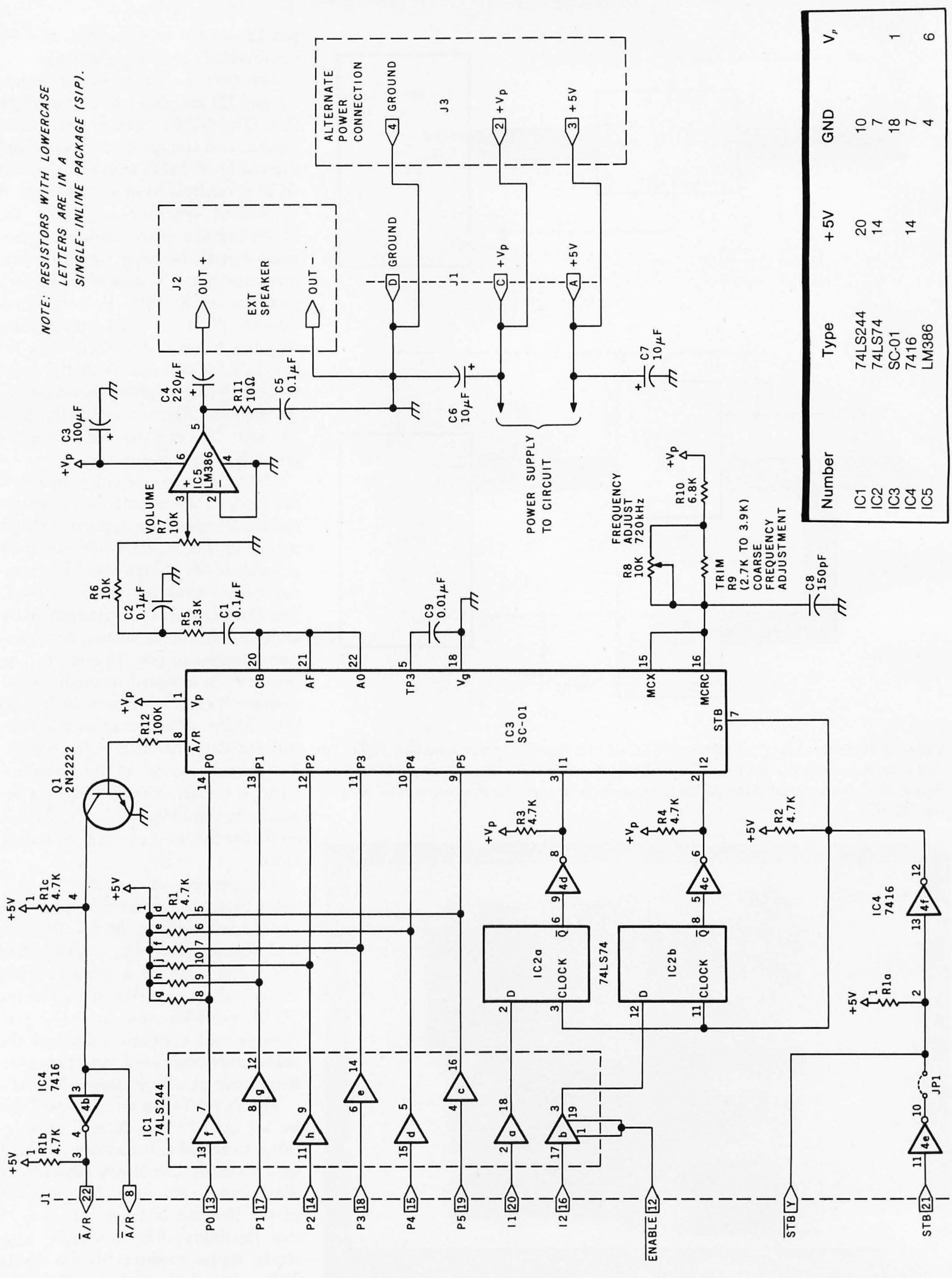
pin 12) should be grounded, thereby continuously enabling the buffer.

The two manual-inflection inputs (I1 and I2) are also buffered through IC1. The SC-01 cannot store these signals, and storage must be provided externally. A 74LS74 type-D flip-flop (IC2) is configured as a 2-bit latch. It is clocked synchronously with the SC-01's strobe input. Unlike the phoneme inputs, however, the inflection lines are not 5 V compatible. Two sections of a 7416 open-collector inverter (IC4) are used with pull-up resistors to level-shift these data inputs to CMOS levels. Since the automatic inflection is generally adequate, the manual-inflection inputs (J1, pins 16 and 20) can be left open or grounded when not in use.

The SC-01 can use either its internal clock or an external clock. External clock signals are applied through pin 15 on the SC-01 while pin 16 is grounded. My design uses the internal clock-signal generator, instead. The clock frequency is determined by an R/C (resistor/capacitor) combination attached to pins 15 and 16. The frequency is adjusted through potentiometer R8 and nominally set for 720 kHz. Slight adjustments to this control will vary the pitch of the speech. The easiest way to set this potentiometer is by ear. Simply output a sequence of phonemes to the SC-01 and set R8 for the most pleasant-sounding voice.

The process of sounding a phoneme begins when the 6-bit phoneme code is latched into the SC-01's control register. Latching occurs when the rising edge of a positive-going strobe pulse is received on pin 7 of the SC-01, the STB input line. The synthesizer will continue to sound the same phoneme until another phoneme code or a stop code is loaded.

The Sweet Talker circuit board can be set up (through jumper connections) to accept either a normally high or a normally low strobe signal from the external computer. Two sections of the inverter IC4 are involved in this flexibility. The normally high strobe signal connects to the Sweet Talker board through pin Y of the edge connector J1, while the normally



Number	Type	+5V	GND	V_p
IC1	74LS244	20	10	
IC2	74LS74	14	7	
IC3	SC-01		18	1
IC4	7416	14	7	
IC5	LM386		4	6

Figure 4: *Schematic diagram of the Sweet Talker phonetic speech synthesizer in the parallel-port version.*

low strobe signal connects through pin 21. The two inputs cannot be used in exactly the same way, however, because of some timing restrictions imposed by the SC-01.

The SC-01 senses the positive-going edge of the strobe pulse arriving on its pin 7, but unlike typical TTL latches (which operate in a few nanoseconds), the SC-01 requires some setup time before it can accept the strobe signal. This setup time must meet two requirements:

- The data on the phoneme-input lines P0 through P5 must have been stable for 450 ns before the rising edge of the strobe pulse arrives.
- The logic level on the STB input of the SC-01 (pin 7) must have been low during at least 72 clock periods (approximately 100 microseconds) before it goes high for the strobe pulse.

The staggered timing of the phoneme data and the strobe pulse makes interfacing the SC-01 directly to a microcomputer data bus difficult without the use of an external data latch (an output port).

Furthermore, in some cases (depending upon the method of connection), when the Sweet Talker board is being driven through a parallel output port that uses a DAV (data available) strobe signal, you may have to add a one-shot (monostable multivibrator) to the circuit to stretch the signal out so that the logic level at pin 7 of the SC-01 stays low long enough. The DAV strobe signal of a typical microprocessor is less than a microsecond in length.

Approximately 500 nanoseconds after the rising edge of the strobe pulse, the $\overline{A}$/R line (pin 8) of the SC-01 goes to a logic 0, indicating that the synthesizer chip is busy. Transistor Q1 and IC4 convert the CMOS output of pin 8 to LSTTL levels. The $\overline{A}$/R output can be monitored by the controlling computer in either of two ways: directly through an input port or connected to an interrupt line. In either case, when the $\overline{A}$/R line returns to the logic-1 level, the SC-01 is ready to receive another phoneme code.

The remaining components on the Sweet Talker board make up the amplifier and filter sections. Capacitors C1 and C2 and resistors R5 and R6 form a simple low-pass audio filter. The audio signal is then amplified by an LM386 1-watt amplifier (IC5) to drive an 8-ohm speaker directly. Potentiometer R7 controls the volume, and the speaker connects to the 2-pin connector on one corner of the board.

The board operates on power-supply voltages of +5 V and V_p. V_p can be any voltage between +7 and +14 V. I generally use +12 V. Power can be applied either through the edge connector or the 4-pin power header. Pin assignments on the power header are arranged exactly the same as those on the Z8-BASIC Microcomputer board presented in my last two articles, and the Sweet Talker board can conveniently use the same power supply. (See "Build a Z8-Based Control Computer with BASIC," July 1981 BYTE, page 38 and August 1981 BYTE, page 50.)

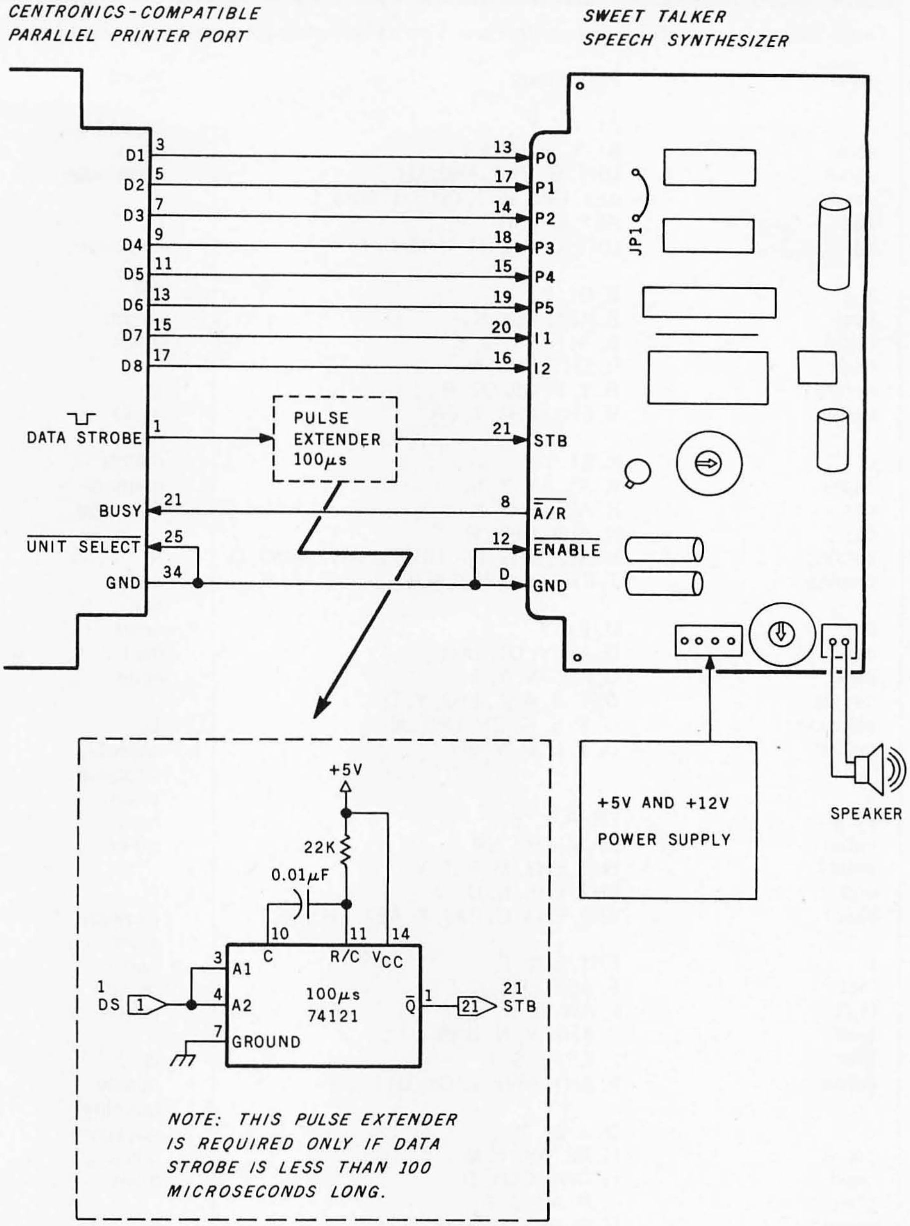


Figure 5: *Diagram of the connections between a Centronics-compatible parallel printer port (as on a TRS-80 Model I or III) and the Sweet Talker circuit board. Note that on some computers the $\overline{\text{Unit Select}}$ line may need to be connected to +5 V.*

Table 2: *A list of useful words with their Votrax-notation phonemes, for ease in program coding.*

Word	Phonemes
A	A1, AY, Y
able	A1, Y, B, UH3, L
about	UH1, B, UH2, AH2, U1, T
actual	AE1, EH3, K, T, CH, U1, UH3, L
add	AE1, EH3, D
adjust	UH1, D, J, UH1, UH3, S, T
B	B, E1, Y
back	B, AE1, AE1, K
basic	B, A1, Y, S, I2, K
been	B, EH1, EH3, N
before	B, Y, F, O2, O2, R
better	B, EH1, EH3, T, ER
C	S, E1, Y
came	K, A1, AY, Y, M
can	K, AE1, EH3, N
car	K, AH2, UH3, R
catalog	K, AE2, EH3, DT, UH3, L, AW2, AW2, G
change	T, CH, A1, AY, Y, N, D, J
D	D, E1, Y
data	D, A2, Y, DT, UH1
date	D, A2, AY, Y, T
decide	D, Y, S, AH2, EH3, Y, D
decision	D, Y, S, I2, ZH, UH3, N
deliver	D, Y, L, I2, V, ER
E	E1, Y
early	ER, R, L, Y
either	E1, Y, THV, ER
empty	EH2, EH3, M, P, T, Y
end	EH2, EH3, N, D
exact	EH2, EH3, G, PA0, Z, AE2, EH3, K, T
F	EH1, EH2, F
fact	F, AE2, EH3, K, T
fault	F, AW, L, T
final	F, AH2, Y, N, UH3, L
first	F, ER, R, S, T
follow	F, AH1, AW2, L, O1, U1
G	D, J, E1, Y
game	G, A2, AY, Y, M
good	G, OO1, OO1, D
great	G, R, A2, Y, T
ground	G, R, AH1, UH3, W, N D
grow	G, R, O1, U1
H	A1, AY, Y, T, CH
hand	H, AE1, EH3, N, D
have	H, AE1, EH3, V
hear	H, AY, I3, R
heavy	H, EH1, V, Y
high	H, AH1, EH3, Y
I	AH1, EH3, I3, Y
important	I1, I3, M, P, O2, O2, R, T, EH3, N, T
include	I1, I3, N, K, L, IU, U1, U1, D
inform	I1, I3, N, F, O2, O2, R, M
insert	I1, N, S, R, R, T
instead	I1, I3, N, S, T, EH1, EH3, D
J	D, J, EH3, A1, AY, Y
job	D, J, AH1, UH3, B
join	D, J, O1, UH3, I3, AY, N
joy	D, J, O1, UH3, I3, AY
judge	D, J, UH1, UH2, D, J
jump	D, J, UH1, UH2, M, P
K	K, EH3, A1, AY, Y
keep	K, E1, Y, P
key	K, E1, Y

Word	Phonemes
keyboard	K, AY, Y, B, O1, O2, R, D
kill	K, I1, I3, L
knowledge	N, AH1, UH3, L, I3, D, J
L	EH1, EH3, UH3, L
language	L, AE1, EH3, NG, G, W, I1, D, J
large	L, AH1, R, D, J
left	L, EH1, EH3, F, T
length	L, EH1, EH3, NG, TH
listen	L, I1, I3, S, I2, N
M	EH1, EH2, M
make	M, A1, AY, Y, K
many	M, EH2, EH2, N, Y
match	M, AE1, EH3, T, CH
memory	M, EH1, EH3, M, ER, Y
message	M, EH1, EH3, S, I2, D, J
N	EH1, EH2, N
name	N, A1, AY, Y, M
near	N, AY, I1, R
need	N, E1, Y, D
next	N, EH1, EH3, K, PA0, S, T
none	N, UH1, UH3, N
O	O2, O1, U1
object	UH1, B, D, J, EH1, EH3, K, T
obsolete	AH1, UH3, B, S, UH3, L, AY, Y, T
often	AW2, AW2, F, I3, N
omit	O1, U1, M, I1, I3, T
other	UH1, UH3, THV, ER
P	P, E1, Y
package	P, AE1, EH3, K, I1, D, J
paper	P, A1, Y, P, ER
part	P, AH1, R, T
person	P, ER, S, UH1, N
phone	F, O1, U1, N
Q	K, Y1, IU, U1, U1
qualify	K, W, AW1, L, I1, F, AH1, EH3, Y
quantity	K, W, AH1, N, T, I3, T, Y
question	K, W, EH1, EH3, S, T, CH, UH3, N
quick	K, W, I1, I3, K
quiet	K, W, AH1, EH3, AY, I2, T
R	AH1, UH2, ER
raise	R, A1, AY, Y, Z
reach	R, E1, Y, T, CH
ready	R, EH1, EH3, D, Y
remain	R, E1, M, A1, AY, Y, N
resistor	R, E1, Z, I1, S, T, ER
S	EH1, EH2, S
safe	S, A1, AY, Y, F
sale	S, A1, A2, AY, UH3, L
schedule	S, K, EH1, EH3, D, J, IU, U1, L
scrap	S, K, R, AE1, EH3, P
section	S, EH1, EH3, K, SH, UH3, N
T	T, E1, AY, Y
talk	T, AW, K
technical	T, EH1, EH3, K, N, I3, K, UH3, L
terminal	T, ER, M, EH3, N, UH2, L
think	TH, I1, I3, NG, K
time	T, AH1, EH3, Y, M
U	Y1, IU, U1, U1
under	UH2, UH2, N, D, ER
uniform	Y1, IU, U1, N, I3, F, O1, R, M
until	UH2, UH2, N, T, I1, I3, L
up	UH1, UH2, P
urgent	R, R, D, J, I3, N, T

Table 2 continued:

Word	Phonemes	Word	Phonemes
us	UH1, UH2, S	when	W, EH1, EH3, N
use	Y1, IU, U1, U1, Z	where	W, EH3, A2, EH3, R
		which	W, I1, I3, T, CH
V	V, E1, AY, Y	while	W, AH1, EH3, I1, UH3, L
vacant	V, A1, Y, K, EH3, N, T	whiskey	W, I1, I3, S, K, AY, Y
valid	V, AE1, UH3, L, I1, D	white	W, UH3, AH2, Y, T
value	V, AE1, EH3, L, Y1, IU, U1	who	H, IU, U1, U1
vendor	V, EH1, EH3, N, D, ER	will	W, I1, I3, L
vent	V, EH1, EH3, N, T	window	W, I1, N, D, O1, U1
verify	V, EH1, R, I3, F, AH1, EH3, Y	winter	W, I1, I3, N, T, ER
very	V, EH1, R, Y	wire	W, AH1, EH3, AY, R
via	V, E1, AY, UH2, UH3	with	W, I1, I3, TH
victor	V, I1, I3, K, T, ER	withdraw	W, I1, I3, TH, D, R, AW
voice	V, O1, UH3, I3, AY, S	without	W, I1, I3, TH, UH2, AH2, U1, T
void	V, O1, UH3, I3, AY, D	word	W, ER, R, D
volt	V, O2, O2, L, T	work	W, ER, R, K
volume	V, AH1, UH3, L, Y1, IU, U1, M	wrong	R, AW, NG
W	D, UH1, B, UH3, L, Y1, IU, U1	X	EH1, EH2, K, PA0, S
wage	W, A1, AY, Y, D, J	X-ray	EH1, EH2, K, PA0, S, R, A1, I3, Y
wait	W, A1, AY, Y, T		
want	W, AH1, UH3, N, T	Y	W, AH1, EH3, I3, Y
was	W, UH1, UH3, Z	Yankee	Y1, AE1, EH3, NG, K, E1, Y
wash	W, AW, SH	yard	Y1, AH1, R, D
water	W, AH1, UH3, T, ER	year	Y1, AY, I3, R
watt	W, AH1, UH3, T	yellow	Y1, EH1, EH3, L, O1, U1
wave	W, A1, AY, Y, V	yes	Y1, EH3, EH1, S
we	W, E1, Y	yesterday	Y1, EH3, EH1, S, T, ER, D, A1, I3, Y
weapon	W, EH2, EH2, P, UH1, N	yet	Y1, EH1, EH3, T
Wednesday	W, EH1, N, Z, D, A1, I3, Y	your	Y, O2, O2, R
week	W, E1, Y, K		
weigh	W, A2, A2, Y	Z	Z, E1, Y
went	W, EH1, EH3, N, T	zap	Z, AE1, EH3, P
west	W, EH1, EH3, S, T	zero	Z, AY, I1, R, O1, U1
wet	W, EH1, EH3, T	zone	Z, O1, U1, N
what	W, UH3, UH1, T	zulu	Z, IU, U1, L, IU, U1
wheel	W, E1, Y, L		

Speaking in Phonemes

Table 1 lists the 64 basic phonemes of the English language. At first glance, it appears complicated, but it is easy to understand and use. Take the word "call," for example. It is made up of three distinct phonemes, as follows (expressed in Votrax notation):

K, AW, L

which correspond to the hexadecimal codes:

19 3D 18

Similarly, the word "disk" is broken into the phonemes:

D, I1, S, K

which correspond to the hexadecimal codes:

1E 0B 1F 19

See reference 3 for more details on this process.

Causing the synthesizer to speak either of these words is done simply by sending the hexadecimal codes sequentially to it. This is most easily done through a parallel I/O port under control of a program written in BASIC. Typically, if the synthesizer were connected to port 0 on your computer, the routine for saying "call" would be coded as follows:

```
100  DATA 25, 61, 24  :REM
     Decimal Phoneme codes for
     "call"
110  FOR A=1 TO 3 : READ P(A)
     :NEXT A
130  FOR A=1 TO 3
140  OUT 0,P(A)  :REM Latch
     Phoneme code into SC-01
150  IF INP(0)=0 THEN GOTO
150  :REM Continue if A/R not busy
160  NEXT A
170  OUT 0,63  :REM Send STOP
     code to SC-01
180  END
```

Essentially any word or series of words can be spoken using this method. It isn't necessary for you to acquire special knowledge about word sounds to use a phonetic speech synthesizer, because many lists of word and phoneme equivalents are available. Table 2 is a list of some common words. A more extensive list is in preparation.

Easy Interfacing

What could be easier than pretending that the Sweet Talker speech synthesizer is a parallel-interfaced printer? It just so happens that many computers already have a parallel output port in the form of a Centronics-compatible parallel printer port. This connection is avail-

Number	Type	+5V	GND	−12V	+12V
IC1	COM5016	2	11		9
IC2	COM2017	1	3	2	
IC3	CD4049	1	8		
IC4	MC1489	14	7		
IC5	MC1488		7	1	14

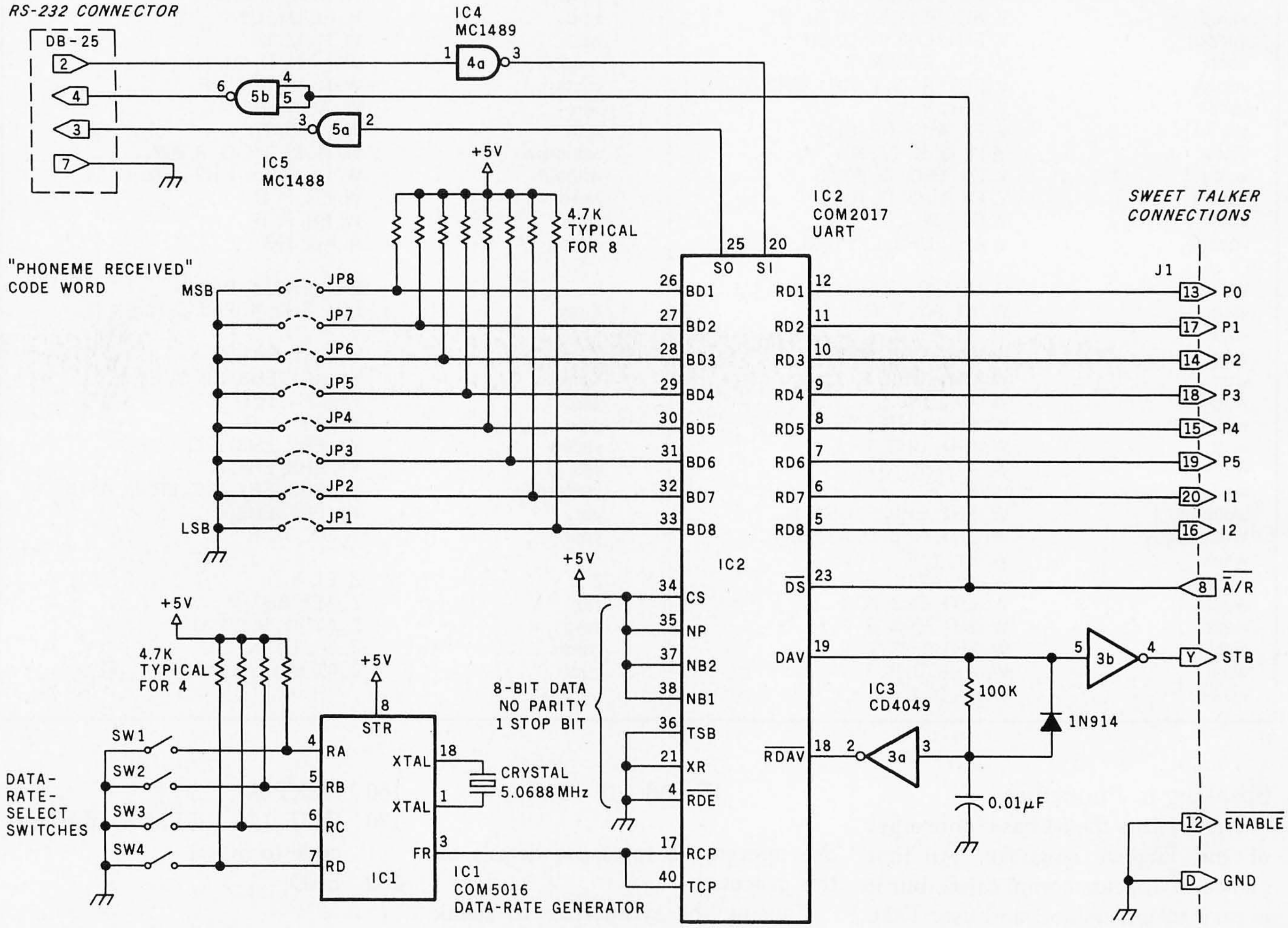


Figure 6: *Schematic diagram of a serial I/O interface for the Sweet Talker board, to be used in place of parallel I/O. The serial communication protocol is RS-232C.*

able on all Radio Shack TRS-80 Model III and expanded Model I computer systems, as well as many others. By connecting the Sweet Talker board as shown in figure 5, it is possible to fool the computer into thinking that the Sweet Talker is a printer, whereupon we can use LPRINT statements to drive it. The same machine-language routine in the BASIC interpreter that normally transfers ASCII (American Standard Code for Information Interchange) character strings to the printer will also work with the speech synthesizer.

A BASIC LPRINT statement will transmit any ASCII characters between the double quotes (except the quotation marks themselves and perhaps a few control codes) whether they spell out something humanly coherent or not. As table 1 illustrates, all of the phonemes correspond to ASCII characters which produce the equivalent 6-bit code (the lowercase letters "a" through "z" correspond to hexadecimal codes 21 through 3A). It is possible, therefore, to type an "@" for the EH3 phoneme (hexadecimal code 00) or a ">" for PA1 (hexadecimal code 3E). Using this technique, the program statement for saying "call" would be:

```
100 LPRINT "Y=X"
```

It's a good idea to add a stop phoneme (corresponding to ASCII "?") after the end of the word to cancel the last phoneme. The line then becomes:

```
100 LPRINT "Y=X";"?";
```

The Sweet Talker speech synthesizer attaches to and handshakes with the computer in the same manner as a printer would. The $\overline{A}$/R output is

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connected to the Busy input, and the Unit Select line is grounded to simulate printer attachment. The Sweet Talker's Enable input should also be grounded. The computer's LPRINT driver routine sends one character to the "printer" (speech synthesizer) and then checks the Busy line before sending another. When the Busy line is high again, the next character (phoneme) is sent.

The only area for concern is the pulse width of the data strobe (attached to J1 pin 21 with jumper JP1 installed), as I previously mentioned. If it is less than 100 μs, a type-74121 monostable multivibrator should be added as indicated in figure 5. If you are unsure of the duration, add the circuit anyway.

Once the interface is attached, a simple program can be used to test phoneme combinations. For example, sending "S*1L/@*KY" will cause the unit to say "automatic," and "Y2M*KIMB677" will make it say "continue." A simple test program requires only three lines:

```
100  INPUT A$
110  LPRINT A$;"?";
120  GOTO 100
```

Using a Serial Interface

Your computer might not have a parallel printer port, but a serial one instead. While the interface is more complicated, you can also use LPRINT statements to drive the additional circuitry shown in figure 6. This circuit is a full-duplex RS-232C serial interface which is capable of receiving a phoneme transmitted serially from the computer, converting it back to parallel form, and strobing it into the SC-01.

The timing relationships between the interface and the computer become slightly more complex. Whenever a phoneme is loaded into the SC-01, the A/R line drops and the RS-232C Data Terminal Ready signal goes low. After the phoneme has concluded, the UART (universal asynchronous receiver/transmitter) transmits a jumper-selected character (optionally preset on UART pins 26 through 33) and raises the Data Terminal Ready line again. Proper timing from the host computer can be accomplished either by sending successive characters only in response to the "phoneme-concluded" code or by monitoring the state of the Data Terminal Ready line.

The communication rate between the host and the synthesizer is switch-selectable from 50 to 19,200 bps using the COM5016 data-rate generator as shown. Communication is hard-wire selected for 8-bit data words, no parity bit, and 1 stop bit. A more in-depth discussion of the data-rate generator and UART was given in one of my previous Circuit Cellar articles ("I/O Expansion for the TRS-80, Part 2: Serial Ports," June 1980 BYTE, page 42).

In Conclusion

What can you do with a computer-controlled speech synthesizer? I'm sure you have a few ideas. In any case, the benefits of electronic speech synthesis will surely propagate as more people learn how to use it.

Next Month:

A discussion of EPROM programming and the design of an intelligent EPROM programmer. ■

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Editor's Note: *Steve often refers to previous Circuit Cellar articles as reference material for the articles he presents each month. These articles are available in reprint books from BYTE Books, 70 Main St, Peterborough NH 03458.* Ciarcia's Circuit Cellar *covers articles that appeared in BYTE from September 1977 through November 1978.* Ciarcia's Circuit Cellar, Volume II *presents articles from December 1978 through June 1980.*

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System Review

The Big Board
A Z80 System in Kit Form

David Thompson
11740 NW West Rd
Portland OR 97229

I built the computer on which I'm writing this article. Even though I'm no expert at computer hardware or software, I assembled this system in a matter of weeks, beginning with a kit called the Big Board.

Manufactured by Digital Research Computers of Texas, the Big Board is a single-board computer that packs an impressive set of features into an inexpensive package. By not providing the cabinet, power supply, keyboard, monitor, and disk drives, Digital Research can sell this heart of a powerful Z80-based system for $650 in kit form. For an additional $50, the board comes with all the sockets soldered in place—a real convenience since all the integrated circuits are socketed.

The board is the size of an 8-inch disk drive. It includes 64 K bytes of programmable memory, a 24-line by 80-character video generator, a keyboard interface, room for four 2 K-byte ROMs (read-only memories, "bank switched" along with the video memory), and a floppy-disk drive controller. Options include parallel and serial ports and an on-board timer.

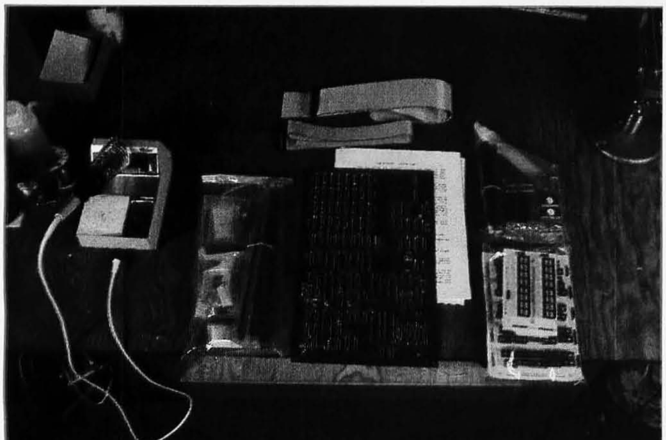

Photo 1: *The Big Board kit as the author received it. The board itself is in the center, with the documentation partly beneath it. On each side are plastic bags containing parts. Cables with connectors are in the rear.*

History

About three years ago, J B Ferguson, an electrical engineer from Dallas, wire-wrapped together a Z80-based, single-board computer and showed it to Jim Tanner of Digital Research. They then worked together to design a powerful, yet inexpensive, unit.

Because of the small size of the board, they used LS (low-power Schottky) parts to keep heat problems to a minimum. According to Tanner, this choice almost killed the project. As recently as January 1980, LS parts were very expensive—too expensive, Tanner and Ferguson believed, for the Big Board to be salable. However, prices dropped so substantially before the end of that year, for both the LS parts and the memory, that Tanner and Ferguson decided to market the unit with a full 64 K bytes of user memory.

Russell Smith designed the Big Board's monitor ROM and the custom BIOS (basic input/output system) for CP/M. The initial plan was to offer CP/M 1.4 with the board. But when version 2.2 became available, Smith went back to work and revised the BIOS. Source listings for both the monitor and BIOS are available free from Digital Research. Just ask for them when ordering the kit.

The Kit

The quality of the circuit board is readily apparent. It is solder-masked and tinned, which makes soldering easy. Solder-masking covers all the metal on the board except for spots where leads will be soldered. The component outlines and numbers are silk-screened on the top, and the holes for the component leads are plated through (they have metal deposited inside them to insure good connections).

At a Glance

Name
Big Board

Manufacturer
Digital Research Computers of Texas
POB 401565
Garland TX 75040
(214) 271-3538

Price
Bare board with the monitor and character ROMs, $195
Complete kit with sockets and ICs, $649
Complete kit with sockets already soldered in place; $699

Dimensions
8.5 by 13 inches

Processor
Z80A

System clock frequency
2.5 MHz

Memory
64 K-byte dynamic programmable memory; four 2 K-byte ROMs (bank switched); 4 K-byte static video memory (bank switched)

Mass storage
On-board controller for up to four 8-inch floppy-disk drives (single-density; each disk holds 240 K bytes formatted)

Other hardware features
Parallel port for ASCII-encoded keyboard; 24-line by 80-character video generator (composite or separated sync)

Options
Real-time clock; two RS-232 serial ports; two parallel ports (adding the options is simply a matter of plugging in the devices and adding a few resistors and capacitors)

Software
2 K-byte monitor ROM (comes with the kit); CP/M 2.2 is available completely configured for an additional $150

Comments
Putting the kit together requires some experience handling static-sensitive parts and a soldering iron. Some knowledge of 8080 or Z80 machine language or assembly language is important.
Be sure to ask for a listing of the ROM monitor and the BIOS (basic input/output system) when ordering your board. The listings are free for the asking.

Although the Big Board's documentation is not as detailed or well organized as Heathkit's, it is well written and contains the information needed. The assembly process is explained step by step, complete with boxes you can check off. Because the parts' names and outlines are stenciled in place, the process takes only a few hours.

What You Must Know

If you have had a high school electronics class, can solder with a small iron, and know how to handle static-sensitive parts, you should have little trouble building the Big Board. But there is more to getting a system running than simply building the board. Though the Big Board is well designed and easy to interface with the keyboard, video monitor, and disk drive, interfacing with other peripheral devices requires some understanding of the hardware, the monitor, and the operating system. For in-

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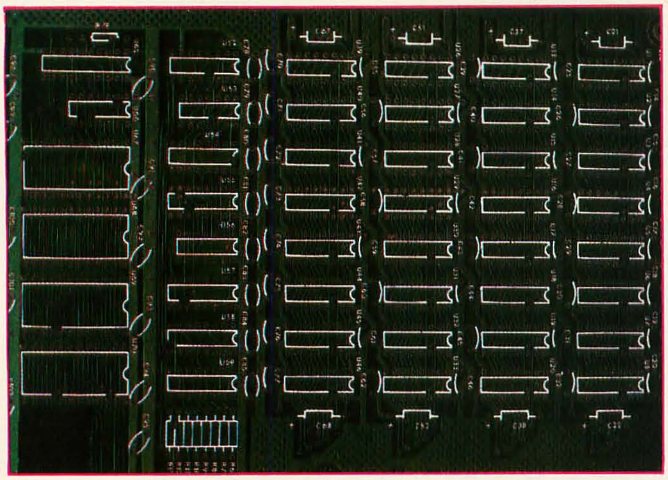

Photo 2: *The empty printed-circuit board. Location markings and some circuitry are visible.*

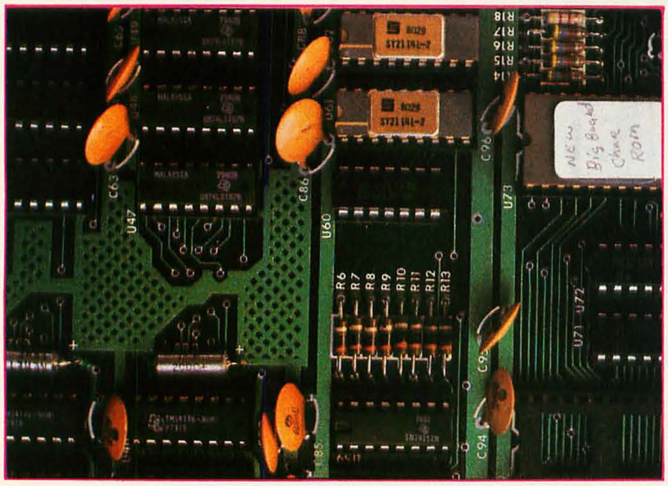

Photo 3: *Close-up of the printed-circuit board showing all the parts in place.*

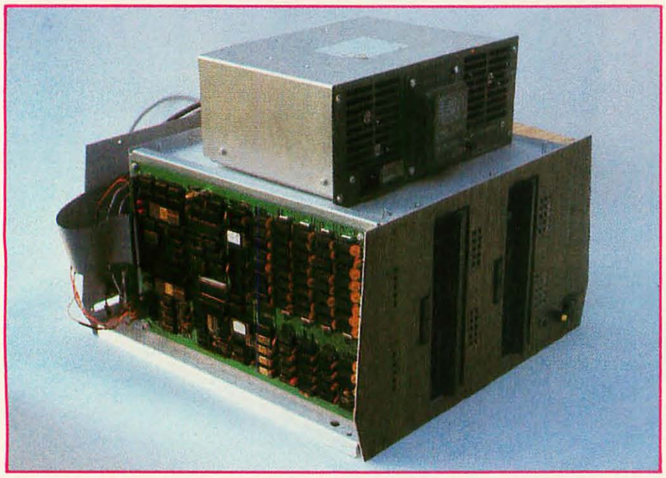

Photo 4: *The Big Board in place in the author's system. Resting on top of the cabinet is the power supply, originally built for a Digital Equipment Corporation controller.*

stance, to interface a modem or printer, you will need some assembly code. Until you write code to convince the Big Board that something else out there "understands" it, it will continue to output everything to the screen. Fortunately, there is a vast, growing national user's group to help you bring up and interface the Big Board.

When I received this board, I didn't understand operating systems and had never written anything in assembly language. Part of the reason I got the Big Board was to learn these things. It was an incredible feeling, after building the board, to watch the operating system sign on, and later to see the first lines of text rasp their way across the printer platen. I knew that I would never again have to update listings by hand while seeing the latest version on the video monitor.

And Once It's Running

Once it's running, what can the Big Board do? The ROM-based monitor program that comes with the board gives you access to all the user memory and ports, lets you test memory to verify that it is operating properly, and lets you look at specific tracks and sectors on disks. If you purchase the custom CP/M 2.2 available with the board, you gain access to a world of utilities, languages, games, and applications programs.

The Big Board is also electrically versatile. If you connect a standard terminal to the serial port (RS-232), the computer will make that port its standard input/output interface. Or if you are using a separate keyboard and video unit, you can select an output video signal to match almost any monitor made. The manual contains complete information on setting jumpers, including an example for the standard composite video monitor.

How well does the Big Board work? So well that my only real complaint, dealing with the character set, has already been corrected. The vast majority of people who have bought one have had no problems. Considering the complexity of the Big Board, this is a remarkable achievement.

Conclusions

If you are interested in building a powerful system, or in learning what goes on in the "engine room" of a microcomputer, or if you've ever had the urge to push the levers, blow the whistle, and increment the A register, Big Board is certainly one way to do it. When you get done, you'll have a truly personal system for less than half the price of a "canned" system. And your system will be able to perform complex tasks like text editing. I use my Big Board for all my writing at home, including letters to relatives, notes to myself, and this article.■

The author is now publishing Micro Cornucopia, *a magazine about the Big Board. The magazine appears bimonthly at an annual subscription rate of $12. For further information, send a SASE to David Thompson, 11740 NW West Rd, Portland OR 97229.*

The Xerox Alto Computer

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Livermore CA 94550

In the mid-1970s, the personal-computer market blossomed with the introduction of the Altair 8800. Each year since has brought us personal computers with more power, faster execution, larger memory, and better mass storage. Few computer enthusiasts or professionals can look at the machines of today without wondering: What's next?

The Alto: a Personal Computer

In 1972, Xerox Corporation decided to produce a personal computer to be used for research. The result was the Alto computer, whose name comes from the Xerox Palo Alto Research Center where it was developed. The Alto was the result of a joint effort by Ed McCreight, Chuck Thacker, Butler Lampson, Bob Sproull, and Dave Boggs, who were attempting to make a device that was small enough to fit in an office comfortably, but powerful enough to support a reliable, high-quality operating system and graphics display. Their goal was to provide each user with a personal computing facility capable of meeting all individual needs and a communications facility that would allow users to share information easily.

Photo 1: *Two of the Xerox Alto personal computers. Each Alto processor is made of medium- and small-scale TTL integrated circuits, and is mounted in a rack beneath two 3-megabyte hard-disk drives. Note that the video displays are taller than they are wide and are similar to a page of paper, rather than a standard television screen.*

In 1978, Xerox donated a total of fifty Altos to Stanford, Carnegie-Mellon, and MIT (Massachusetts Institute of Technology). These machines were quickly assimilated into the research community and rapidly became the standard against which other personal computers were judged.

It is unlikely that a person outside of the computer-science research community will ever be able to buy an Alto. They are not intended for commercial sale, but rather as development tools for Xerox, and so will not be mass-produced. What makes them worthy of mention is the fact that a large number of the personal computers of tomorrow will be designed with knowledge gained from the development of the Alto.

The Hardware

The Alto consists of four major parts: the graphics display, the keyboard, the graphics mouse, and the disk storage/processor box. Each Alto is housed in a beautifully formed, textured beige metal cabinet that hints at its $32,000 price tag. With the exception of the disk storage/processor box, everything is designed to sit on a desk or tabletop.

The Graphics Display

The graphics display is the most striking feature of the Alto. It looks somewhat like a television screen that has been turned sideways (see photo 1). It is a raster-scan display, and the physical dimensions of the screen are 8 inches (horizontal) by 10 inches (vertical). The black-and-white display allows the user to address an area 808 pixels (picture elements) vertically by 606 pixels horizontally. This results in resolution of about 80 points per inch.

The method of display used is called *bit-mapped raster scan*. This means that every point on the display is addressable as a bit in memory. Although this method can take up a great deal of memory, it has the advantage of making the display very

Acknowledgments
I would like to thank Dr Brian Reid and Mark Roberts of Stanford University for their time and helpful comments; also Sandy Lanzarotta of Xerox and Cindy Pavlinac for their help and support.

fast. Bit mapping also provides the user with a convenient method of screen access and the ability to easily look at the current contents of the screen.

In terms of displaying text, the screen can hold 60 lines of 90 characters (assuming the characters are equivalent to the typical 7 by 9 dot character commonly found on most video terminals). Character generation is not done in hardware on the Alto. A character set may be created by a user and displayed on the screen. Mixed fonts are allowed so that text of various sizes and shapes may be simultaneously displayed on the screen.

Since each dot on the display corresponds to only one bit in memory, there is no facility for grays or intermediate intensities. Due to the large number of points per inch, however, various combinations of points can be displayed to form a "texture" that gives the impression of varying shades of gray. This is exactly the same method used to reproduce pictures in a newspaper.

The Keyboard

Superficially, the Alto keyboard resembles a typical typewriter keyboard with the addition of a few special keys. The keyboard is detachable, and quite comfortable for typing. It has the unique property of being entirely unencoded. Each key has its own signal line in the

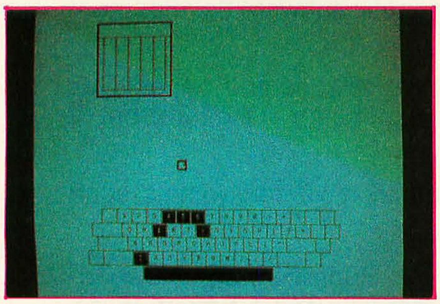

Photo 2: *Display from the keyboard-test program. The Alto keyboard has a separate signal line for each key and can thus tell when any number of keys are being pressed simultaneously. In the display, the black keys are being held down. The small square above the keyboard represents the mouse (see photo 4); one mouse key is also pressed.*

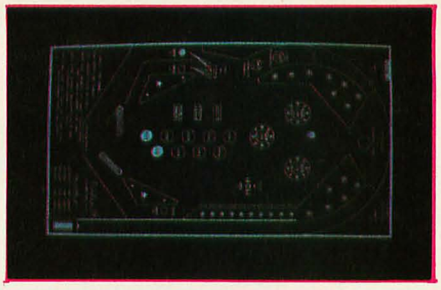

Photo 3: *The Pinball game. Flippers are actuated by the two shift keys; an Alto port can be connected to a speaker to provide bells and buzzer sounds.*

keyboard interface, which allows a program to take advantage of the possibility of "chord" commands, where the user holds down one or more keys. For example, Shift-Control-E is as easy for the Alto to read as A-B-C (see photo 2). Another advantage is the ability to determine how long a key has been held down. For example, the pinball game program in photo 3 determines the force of a shot by measuring how long a key is held down on the keyboard. There is, of course, software to allow a program to read the keyboard in the typical manner.

The Graphics Mouse

The *mouse* is a small box with three buttons on the top and several ball bearings on the bottom. A slender cable connects the mouse to the Alto keyboard (see photo 4). The buttons are named red, yellow, and blue, although the physical buttons are all black. The mouse is typically held in the user's right hand and rolled along the table on a soft piece of plastic that provides traction for the ball bearings.

Movement is detected by the motion of one of the ball bearings. The mouse reports changes in position to the Alto. From this, a cursor on the Alto display can be positioned. The physical position of the mouse on the table is unimportant, since only the change in position is reported. The mouse graphics interface is considerably more flexible and comfortable than a bit pad, joystick, or trackball. Many Alto programs can be controlled with the mouse alone, independent of a keyboard.

The buttons on top of the mouse are also unencoded, for flexibility. Many programs distinguish between holding a mouse button on or clicking it on and off. This allows a program to receive input by moving the cursor to some designated spot on the screen and then touching a mouse button to make something happen.

Disk Storage/Processor Box

The processor and disk storage for the Alto are contained in a rack about the size of a waist-high filing cabinet. Each Alto has two 3-megabyte disk drives. The drives themselves resemble small pizza ovens and are often referred to in this manner.

The "brain" of the Alto is a 16-bit custom-made processor intended to resemble the Data General Nova 1220. The processor is made entirely of small- to medium-scale TTL (transistor-transistor logic) ICs (integrated circuits). The processor operates at a speed of approximately 400,000 instructions per second. Each Alto has an address space of 64 K 16-bit words, including the graphics bitmap. By using a technique called *bank selection*, the Alto may expand its available memory in 64 K-word increments up to 256 K words. An Alto with 256 K words is known as a *wide-bodied* Alto.

Quite a bit of the magic of the Alto is performed at the microcode level. The Alto can run up to sixteen tasks concurrently, and all of the schedul-

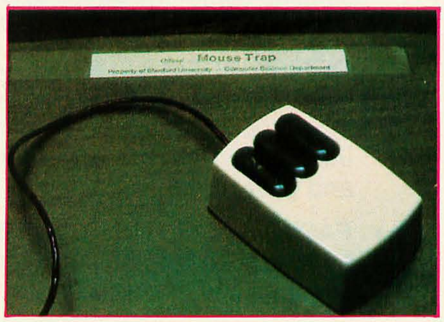

Photo 4: *The mouse input device. The operator uses the mouse to control cursor placement on the screen; it detects its own change in position (a joystick relies on absolute position) as the operator rolls it around on a piece of soft plastic. The mouse also has three buttons, called red, yellow, and blue.*

ing and I/O (input/output) for this multiprocessing is done in microcode. The user has direct control over only one task, however. The user task is the lowest priority and must, if necessary, relinquish processing cycles to the other tasks that control the display, disks, keyboard and mouse I/O, and Ethernet connections. The user has direct control over the microcode and may rewrite it according to individual taste.

The Software

The Alto has the interesting property of using software (often microcode) to perform many tasks, such as keyboard encoding and character generation, that are typically done in hardware. This approach leaves the Alto with an occasionally cumbersome but highly flexible architecture.

Each Alto has a ROM (read-only memory) that contains just enough software to "bootstrap" an Alto into the local network (see textbox on this page). By keeping a bootstrap program in ROM, the user will always have a "safety net" to fall back on in case some other portion of the system software is not working. All of the Alto software can be retrieved from across the network.

The Alto Operating System (OS), a program which provides a set of basic facilities for control and communication with the Alto, is written in BCPL, a language very similar to C. Most programs, BCPL or otherwise, run under the direction of the Alto OS. Since the address space of an Alto is small, a technique called a "Junta" is used to permit BCPL programs to shed unwanted sections of the Alto OS during execution. If those portions are needed later, they may be restored by performing a "Counterjunta."

One BCPL program that runs on top of the operating system is called the Alto Executive (see photo 5a). This program speaks to the user directly and makes facilities available for file manipulation and program execution. An interesting feature of the Executive is that of escape expansion and file-name completion. Typing a partial file or program name followed by an escape, in the same fashion that an ESC (escape) or ALT (alternate mode) might be sent from an ASCII (American Standard Code for Information Interchange) terminal, causes the Executive to complete the typing of the name on the screen. This allows a programmer to name a file in a descriptive manner (such as GatewayInformation.press), rather than typing in a long name. The Executive program will recognize it as soon as it has read enough characters to determine the file uniquely. By

The Ethernet Network: Interconnecting Personal Computers

The Ethernet network, developed at Xerox Palo Alto Research Center by Bob Metcalfe and Dave Boggs, is a medium for the transmission of information. It is a multiaccess broadcast system used to link many computer systems that are physically within several hundred meters of each other. Each machine in the network is connected by means of a single, passive, coaxial cable.

The Ethernet network is a packet network. Information to be transmitted from one node to another is enclosed in an "envelope" of data that describes the information (ie: its length, a checksum for error control) and describes the destination of the resulting datagram or packet.

Regulation of access to the Ethernet cable is performed by a system designated CSMA/CD (Carrier Sense Multiple Access with Collision Detection). This technique works in exactly the same way that conversation among a group of people at a party is regulated. A node with something to say waits until no one else is speaking. When everyone else is quiet, that node begins to broadcast. If another node also starts broadcasting, this is called a collision. When a collision occurs, all of the nodes that are broadcasting cease to do so. Each node waits a random amount of time and then listens for another lull, thus starting the whole process again.

Each node on the network listens to the beginning of each packet. Once a node has determined that a packet is not addressed to itself, it stops paying attention to that packet and waits only for the end of the packet to allow it to prepare to listen to the next one. An Ethernet node may become "promiscuous" and listen to all packets being broadcast. This allows a very precise monitoring of statistics on the Ethernet system, since nodes generating traffic need not perform any statistical processing or use any network bandwidth to report the statistics. A "silent observer" can watch the network without ever affecting the performance of that network.

At first glance, the "cocktail party" approach to multiple access might seem awkward. A second look, however, reveals that the maximum packet length is only 554 bytes, and the speed of Ethernet transmissions is approximately three million bits per second. This leads to a maximum transmission time of about 1.5 ms (milliseconds), which means that even on a highly loaded network, the overall efficiency remains very high.

An interesting aspect is that the Ethernet network itself is entirely passive. Regulation is done by each individual node. This decentralization means that the failure of any single node will not significantly affect the network as a whole. Thus, the mean time between failures of the whole network is very high, making it a good choice for industrial or business applications where downtime means lost revenue.

The high speed of the Ethernet network rivals that of disk I/O. A file may be loaded from across the network almost as easily as from a local disk. In a distributed information processing system, it is highly desirable to allow a file to be easily accessed anywhere on the network. A high-speed file transfer capability also permits a new machine to be integrated into the network in just a few minutes.

The competition in local networking is hot and heavy. DEC (Digital Equipment Corporation), Intel, and Xerox Corporation have recently joined forces to promote an Ethernet-based industry standard network. Wang Corporation, IBM, and Zilog have also proposed networking standards. Whatever the outcome, industry seems to have decided that the future is in local networks.

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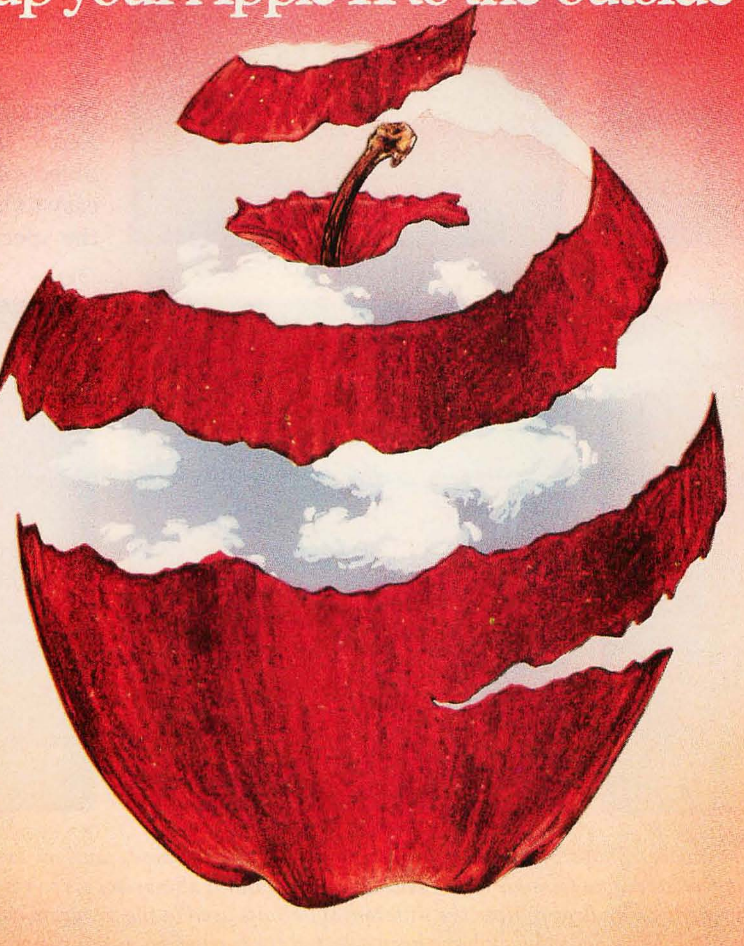

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typing a question mark instead of an escape, the Executive will list all file names that are valid matches for the string typed thus far.

The Alto has a highly flexible and rugged file system. Unlike many file systems (eg: Digital Research's CP/M or Radio Shack's TRSDOS) that limit names to six or eight characters with a three-character extension, the Alto file system permits file names of up to thirty-one characters in length. When a file name is entered for the first time, the file name is stored exactly as typed, even with regard to upper- and lowercase. Since the file names may be very long, this permits a programmer to use upper- and lowercase to improve readability. LongFileName.BigExtension is much easier on the eyes than LONGFILENAME.BIGEXTENSION. After the creation of a file, case is ignored when the user is speaking about the file, so either of the two names in the previous examples, as well as longfile name.bigextension, would be valid.

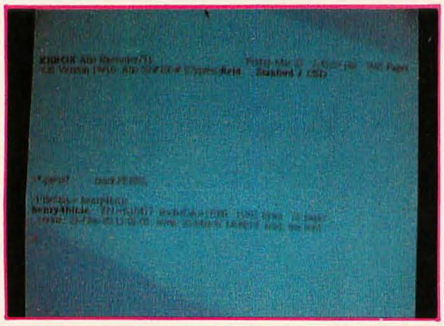
Alto files are divided into *pages*. Each page contains a small header that describes the current page, tells what file the page belongs to, and points to the places on the disk that contain the next and previous pages for the same file. This makes the file system almost indestructible. A program called Scavenger can automatically rebuild a broken file system.

Of course, no Alto is an island, so software is needed to deal with the Ethernet network. Some of this software appears in the form of the NetExecutive (see photo 5b) and FTP (file-transfer program). The NetExec is a program that appears to be very similar to the Alto Executive, but it loads programs from across the network rather than from the local disk. This means that a user need not keep infrequently used or large programs locally. Instead, these programs can be loaded through the network (at an apparent speed of approximately 800,000 bits per second) only when needed. FTP performs similar feats of file manipulation, but in a considerably more flexible manner.

Although a great deal of software written for the Alto is in BCPL, there is a new contender for software development called Mesa. Mesa is a Pascal-like language that is incompatible with BCPL because of differences in their respective microcodes. Mesa is expected to be the programming language for the successors of the Alto (see photo 5c).

BCPL and Mesa are the system languages for the Alto, which means that the system utilities and many applications programs are written in them. Other languages are available on the Alto, however. Much of the research work done on the Alto at Xerox is written in Smalltalk, an object-oriented language that is both easy to learn and highly powerful (see the special August 1981 BYTE issue

(5a)



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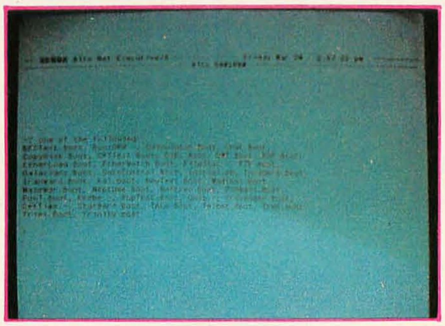

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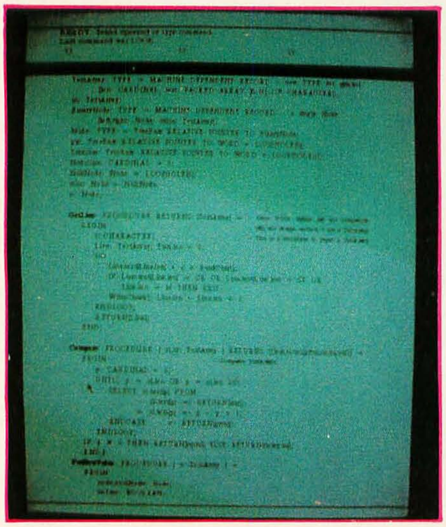

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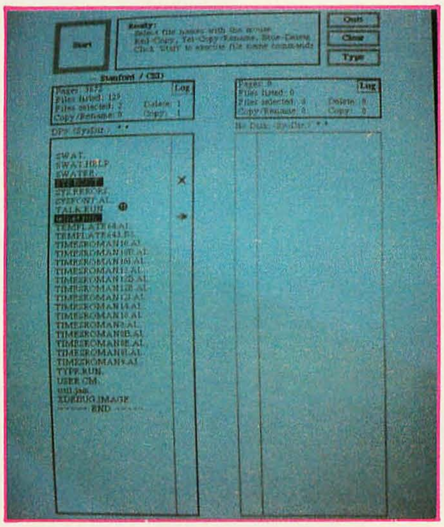

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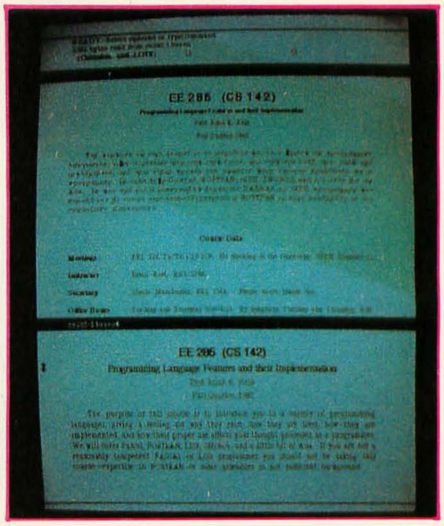

Photo 5: *Examples of Alto software. Photo 5a shows a display of the Alto Executive, with an example of star and question-mark notation. Photo 5b shows the NetExecutive (similar to the Alto Executive, but it allows access to resources on the Ethernet). Photo 5c is a typical Mesa program being edited by Bravo; note the different typefonts used in the program listing. Photo 5d is a directory from the Neptune directory editor. The file names in black have been selected for further operations such as printing or erasure. The cursor is displayed as a cross in a circle. Photo 5e illustrates Bravo's ability to change fonts (there are hundreds of fonts for the Alto, from Gothic to Elvish Runes; the central paragraph in this display has been changed to Greek). The document in the bottom window has been converted to the form shown in the top window.*

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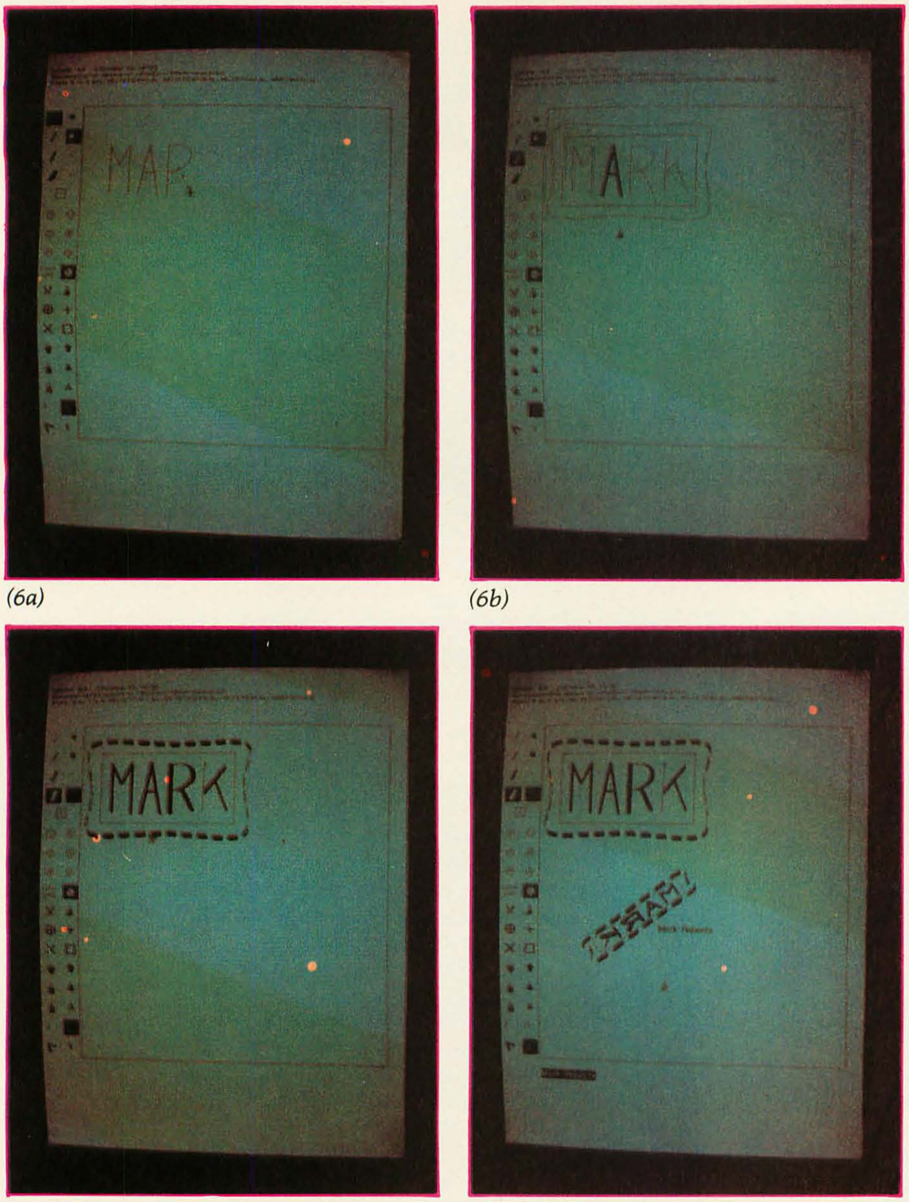

(6a) (6b) (6c) (6d)

Photo 6: *Use of the Draw program. In photo 6a, points are placed with the cursor, and curves and lines are filled in by the program. Photo 6b shows that lines may be "painted" with a variety of "brushstrokes" (the cursor has changed to a small paintbrush). In photo 6c, texture is given to the lines; dotted lines are created with the scissors cursor. Photo 6d shows that the picture may be mathematically manipulated; a new figure may be created by reversing, tilting, or stretching a copy of the original.*

on the Smalltalk language). Another supported language is LISP, a list-processing language that is very popular in the artificial intelligence research community.

Using the Screen

A system with the advanced graphics capability of the Alto will make extensive use of those facilities. The screen may be broken up into windows, and each window may be accessed in a different manner, if desired. Many Alto programs use only the mouse and screen windows for program control. For instance, the Neptune program is used for managing the contents of the Alto's local disks (see photo 5d). A file may be deleted simply by touching the file name with the cursor, then touching the Delete spot on the screen with the cursor. As the cursor enters a new window, it may change shape, perhaps appearing as an arrow in one window and a paintbrush in another.

Since the Alto is used extensively for research in the office automation field, a good text editor is an obvious requirement. Bravo is a text editor and formatter widely used on the Alto. In the tradition of screen-oriented editors, the current state of the user's file is always shown on the screen. Bravo is controlled partly by keyboard commands and partly by mouse commands. It allows a user to open windows into one or more files. Text may be added or deleted by pointing at the desired location on the screen (see photo 5e) with the mouse cursor, and giving a command via the keyboard or mouse. Bravo supports many different fonts and allows the user to change easily from one font to the next. In addition, Bravo remembers the changes that have been made to a document and allows the user to reverse any or all changes.

Bravo allows the user to edit and format text, but often a person may wish to include illustrations in a document. To do this, a program called Draw is used. Draw is an interactive sketch-pad program that provides a variety of tools for creating and manipulating pictures made from lines, curves, and text. Draw divides the screen into a number of windows (see photo 6). The left side of the screen contains a menu of commands and a variety of brushstrokes that can be selected. The top of the screen contains an area for text commands and messages from the program. The middle of the screen is the picture workspace. Curves can be drawn by moving the cursor directly, or by selecting several points and allowing Draw to mathematically fit a curve to those points. Once an object is defined, it can be repainted using a number of brushstrokes. Since this is very similar to the techniques used by artists and calligraphers, quite a bit of artistic expression is possible. An object can be duplicated, rotated, stretched, or shrunk, by means of a small set of commands and mouse gestures.

The Network

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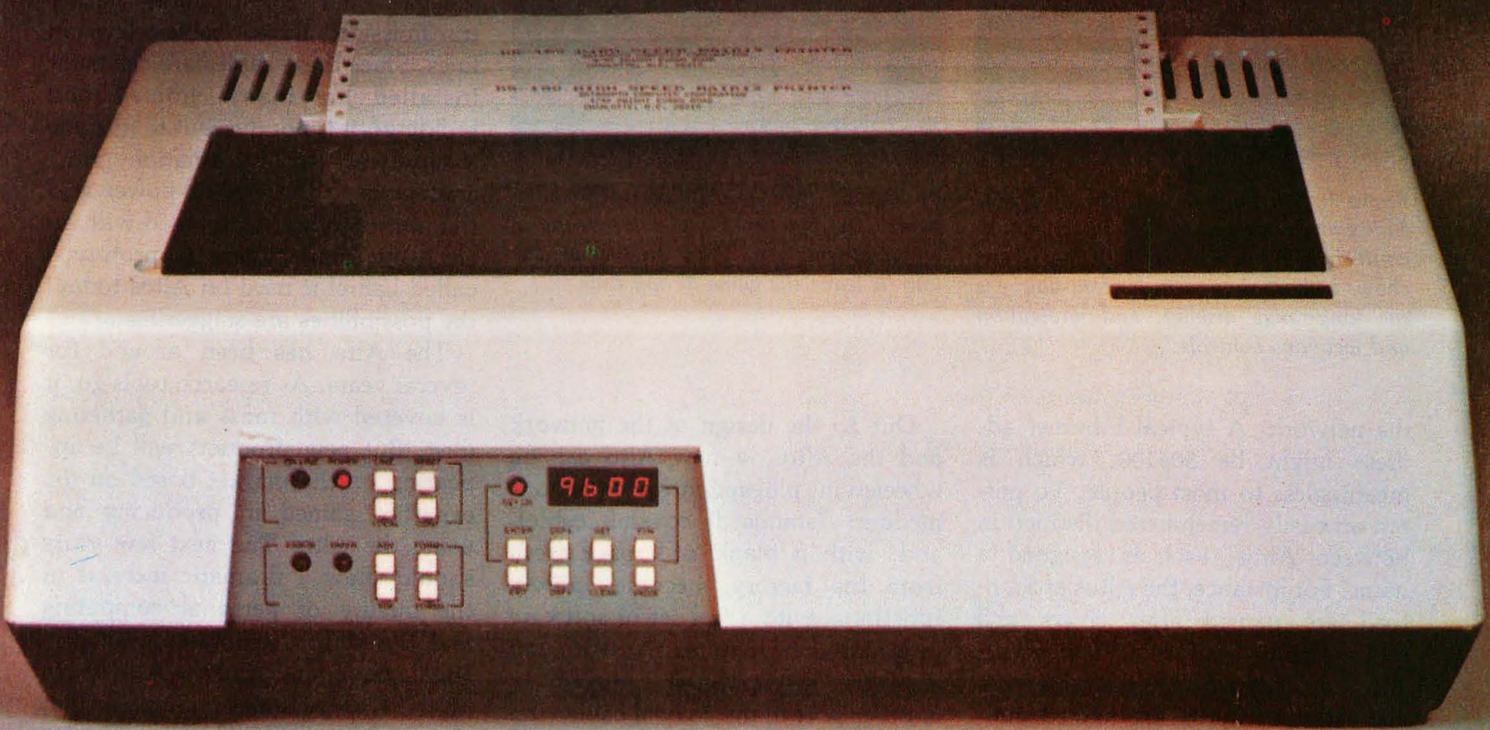

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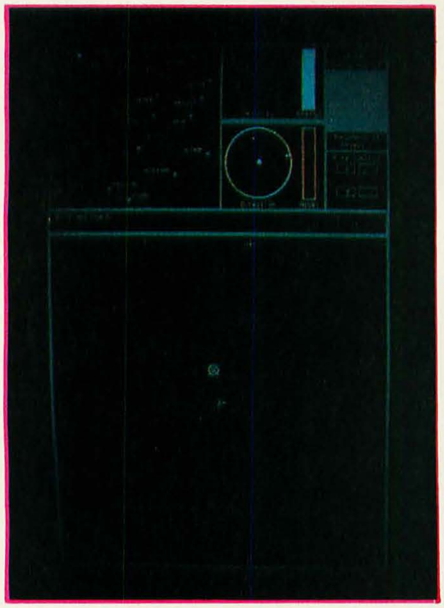

Photo 7: *The multiplayer Trek program. This game is played entirely under mouse control. The lower portion of the screen shows a short-range sensor scan; above is the long-range display, and navigation and weapons controls.*

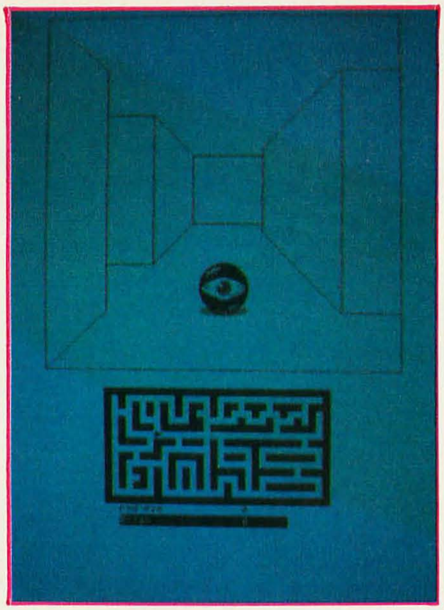

Photo 8: *The multiplayer Mazewar game. The eye represents the persona of an opponent. Any Alto on the net can join or leave the game at any time.*

the network. A typical Ethernet address might be 50#100, which is meaningless to most people. To permit an easily remembered distinction between Altos, each is assigned a name. For instance, the Altos at Stanford are named after rivers and mountains in California State parks; Altos at CMU are named after jewels, and Altos at Xerox are named after people. This leads to such interesting names as Cypress, Turquoise, or Machiavelli, which are considerably easier to remember than 50#100.

Alto networks do not consist entirely of Altos. Several other devices are connected to the Ethernet network. One type is called a *server*. Servers are userless Altos that are dedicated to some specific function. A server might be connected to a printer. Thus, printing a file would actually consist of sending the proper messages to a Printing Server. One common type of server is a File Server. These machines support extra-large disks and are repositories for programs and files that are too large or too infrequently accessed to make storage on individual machines worthwhile. The Stanford File Server is named Lassen.

Due to the design of the network and the Altos, a new Alto can be wheeled in, plugged into the network medium (standard coaxial cable), and, with a blank disk pack fresh from the factory, become entirely functional with a full set of software in a matter of minutes. An Alto can also be disconnected, moved to another port in the coaxial cable, and reconnected without affecting either the performance of the network or the Alto.

Several programs exist that take advantage of the distributed processing capabilities inherent in the Ethernet network. Of all of them, the most enjoyable are the games. Trek is a multiplayer "spacewar" game that is controlled primarily by the mouse (see photo 7). Mazewar is a multiplayer romp through a realistic labyrinth (see photo 8). The unique feature of these games is that large numbers of users can join or leave the game as they please without affecting the play of the others. Since all the Altos can listen to the same packet (block information on the Ethernet) at once, the game program is never running on any single coordinating machine. Instead, it is running independently on every participating Alto.

The Future

A stand-alone Alto is usable, but the best configuration is a group of Altos connected by an Ethernet system. Since the Ethernet system is a local network, a special device called a gateway was developed to allow local Ethernet networks to speak to other Ethernet networks or packet networks of other types. Many companies are researching network schemes that would allow packet transmission across cable-television lines. Since these cables are currently installed in many homes and buildings, it is not difficult to imagine a city with an "information grid," analogous to the electric-power grid that exists today. Combined with an electronic mail system (a prototype called Laurel is used on Altos today) the possibilities are staggering.

The Alto has been around for several years. As research tools go, it is covered with moss and gathering dust. But new products will be appearing on the market based on the expertise gained in producing and using the Alto. The next few years should show a dramatic increase in the quality of personal computing and the ability to interconnect personal computers. And the Alto is one of the first personal computers that satisfies the needs of the computer scientist as well as the secretary or businessman. ■

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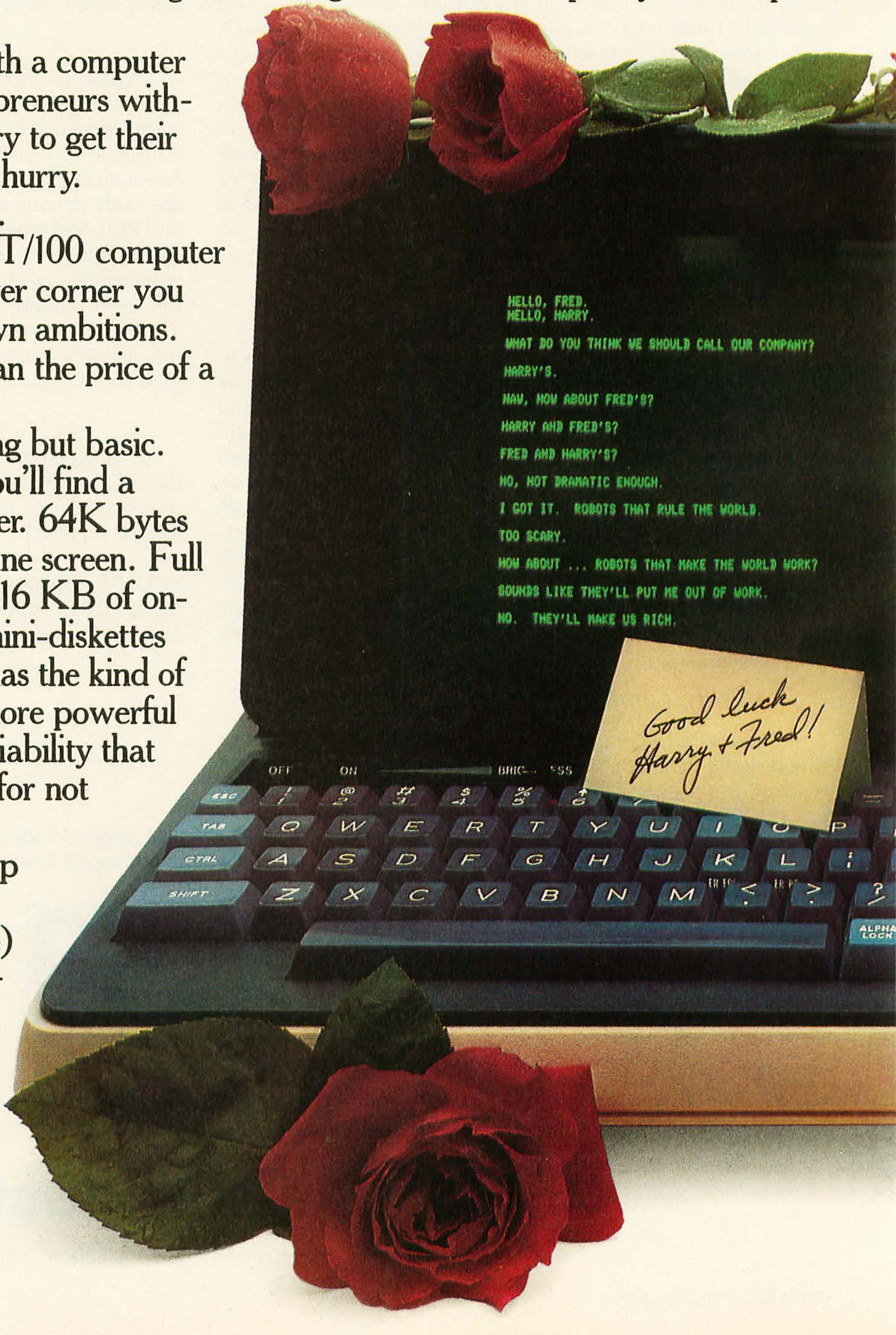

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Tree Searching

Part 1: Basic Techniques

Gregg Williams, Senior Editor

It is estimated that there are more possible games of chess than there are atoms in the universe. This means that if a computer could generate one million chess moves a second, it would take approximately 3.2×10^{60} *centuries* to generate all possible games. How, then, can a \$200 microprocessor-based chess game (faced with analyzing a situation so complex) play not only minimal but fair-to-good chess? Several techniques are necessary, but one of the most powerful in the field of artificial intelligence is known as *tree searching*.

Tree searching allows a computer to determine the best of many alternatives, while at the same time evaluating as few partial solutions as possible. Part 1 of this article deals with the basic techniques of tree searching on three levels: theory, implementation (through several BASIC programs illustrating the major techniques), and experimentation. It will introduce basic terminology and some well-known *exhaustive* tree searches (those that will eventually generate all possible partial solutions), as well as an illustrative BASIC program (to solve the familiar sliding blocks "15-puzzle") that will be used in both articles. The second part will deal with *admissible heuristic searches* that use information about the system being searched to cut down on the number of false leads pursued; it will also cover nonadmissible heuristic searches, which attempt to find a quicker solution at the expense of losing the certainty of a guaranteed *optimal* solution, or of finding a solution at all.

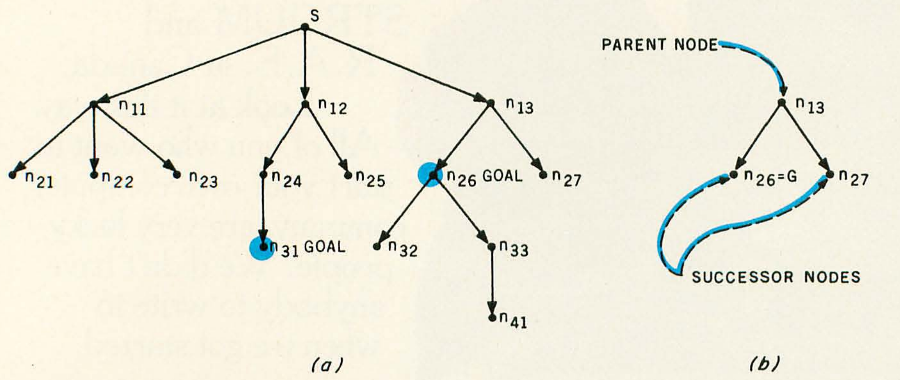

Figure 1: *Nomenclature of trees. Figure 1a gives the graphic representation of the state space of a problem as a tree. Trees are characterized by having only one start node (S), by containing only nodes that can be reached via the start node, and by having no arrows that lead to the same or lesser depth. Nodes n_{21}, n_{32}, and n_{27} are examples of terminal nodes; nodes n_{12}, n_{26}, and n_{33} are examples of nonterminal nodes; nodes n_{31} and n_{26} (shown in color) are goal nodes. Note that a goal node can be either terminal or nonterminal. Figure 1b shows the relationship between parent node n_{13} and successor nodes n_{26} and n_{27}. Here, n_{13} is said to be* expanded *to generate n_{26} and n_{27}.*

Basic Terminology

The purpose of artificial intelligence, according to one school of thought, is to produce computer programs that will solve problems not easily solved by computers—problems that can be solved by an "intelligent" agent (usually a human). The solution to many of these problems can be seen as the attempt to arrive at a solution (or *goal*) whose properties are unambiguously defined, from an initial state (or *node*), according to some specific set of rules. Between the starting node and the goal node are other nodes that represent intermediate positions. We

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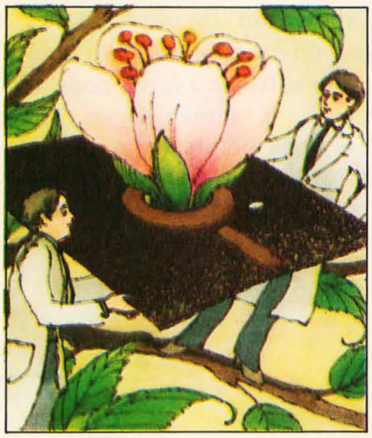

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are interested in the particular sequence of nodes that makes up the shortest path to one of several possible goal nodes. Many nodes (usually an overwhelming number) do not lie on the optimum path, and the purpose of tree-searching methods is to explore as *few* of these as possible.

A number of problems that do not seem to lend themselves to tree searches can be made to do so when described in a *finite-state representation*. Sometimes, in the case of problems that have a continuous (and therefore infinite) range of variation, this means quantizing the problem into a finite number of discrete steps: an example is considering the range of temperatures of 20° to 30°C as a set of discrete temperatures—say, 20.0°, 20.1°, 20.2°, ... 29.9°, and 30.0°. Theoretically, this results in some loss of accuracy, but most problems can be quantized in sufficiently small increments that accuracy is not a problem.

A finite-state representation consists of the following: a *start node*, a well-defined node or *set of goal nodes*, and a set of rules or *operators* that allows the user to generate all permissible successor nodes from a given node. In some cases, the path from a node to its *successor node* (that is, one generated by the single application of an operator to the *parent node*) may have a *cost* associated with it, with the cost of a goal node being the total cost incurred along the shortest path from the start node to the goal node. The set of all nodes that can be derived from the start node is called the *state space*.

A *tree* is one possible representation of the state space of a problem. As shown in figure 1, nodes are represented as points, and the relationship between a given node and its successor is shown by a directed arrow that points from the parent node to the successor node. We will label the start node S, and each of the other nodes according to its *rank* (distance from the start node) and lateral position within the set of all nodes with the same rank (this is an arbitrary labeling, but it is orderly and useful). Referring to figure 1a, nodes n_{11}, n_{12}, and n_{13} are all the nodes of rank one. Node n_{12} has two successor nodes, n_{24} and n_{25}. Node n_{41} is the only node of rank four.

Some nodes do not yield any new states upon application of the operators that define the transition from one state (node) to the next. These are called *terminal nodes*; examples in figure 1a are nodes n_{21}, n_{22}, n_{23}, n_{25}, n_{27}, n_{31}, n_{32}, and n_{41}. Nodes marked G are regarded as goal nodes; they can be either terminal or nonterminal nodes.

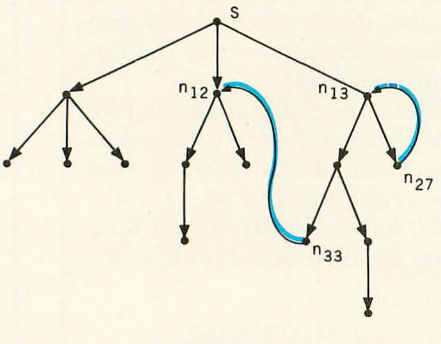

Figure 2: *A directed graph. This figure, which represents the structure of many "real-world" problems, differs from a tree in that successors may be in the same or a "shallower" depth (note colored arrows). The successor of n_{33} is n_{12}; the successor of n_{27} is n_{13}. Tree-searching algorithms can be modified to handle graphs, but this article will deal exclusively with trees.*

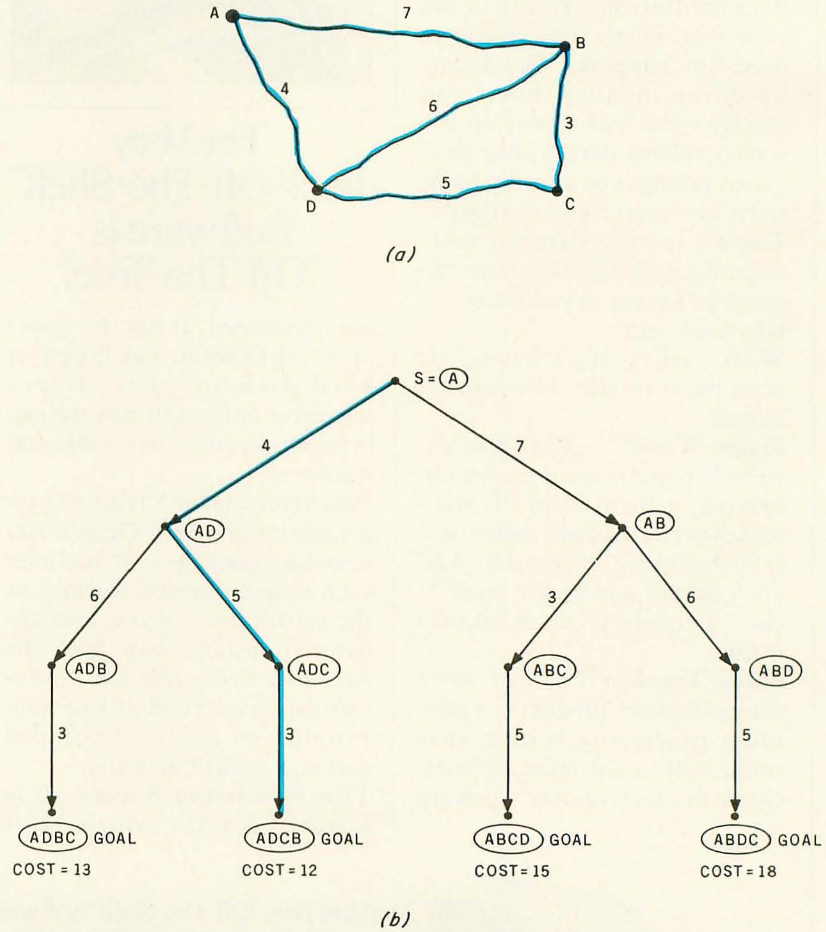

Figure 3: *The traveling-salesman problem. Given the map in figure 3a, the objective is to find the shortest route from city A through cities B, C, and D. The tree of figure 3b gives the finite-state representation of the problem, with each node being a partial trip (eg: ADC is the trip from A through D and C) that has a cost dependent upon the route taken. Here the problem is discrete, and any node has only a finite number of successors; at node AD, only two "next moves" are possible: ADB and ADC. The shortest route is shown in color.*

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Often the state space of a problem will allow a node to generate as successor a node of equal or lesser rank, as shown in figure 2. In this case, the resulting representation is called a *graph* (or, more completely, a *directed graph*). This will call for only a slight addition to the search strategy, but the difference should be noted.

Finally, as mentioned before, a transition from a node to its successor may have a cost associated with it. If so, the arrow connecting the two will be labeled with the cost; otherwise, the arrows are unlabeled and each is assumed to carry a unit cost.

Some Examples

First we will examine a discrete example: the traveling salesman problem. A traveling salesman in city A must travel to cities B, C, and D, in any order. Given the map in figure 3a, what order of cities gives the shortest total mileage?

In this problem, the nodes are partially completed (or completed) trips described by a sequence of the letters A, B, C, and D, restricted by the rules that follow. The start node is A (salesman in city A, no traveling done). Four goal nodes describe various routes, ABCD, ABDC, ADBC, ADCB. The rules are informally described: from a given node, add the letter of any city that connects to the last city visited and that has not yet been visited.

Since the number of cities is small, a full state-space tree is possible (figure 3b), and it is clear that the shortest route is ADBC, with a distance (cost) of thirteen. But what if there are ten cities? Twenty? What if some roads are one-way?

Next we see a continuous example (here the state space must be cut into a finite number of discrete values). You have a faucet, a sink, and an empty glass with a horizontal line on it: fill the glass up to the line.

First we must quantize the problem. Suppose we say that the glass holds 100 ml of water. We can reasonably set the smallest unit of water to be manipulated at one milliliter. The state of the problem is the amount of water in the glass, and the problem has 101 possible states: 0

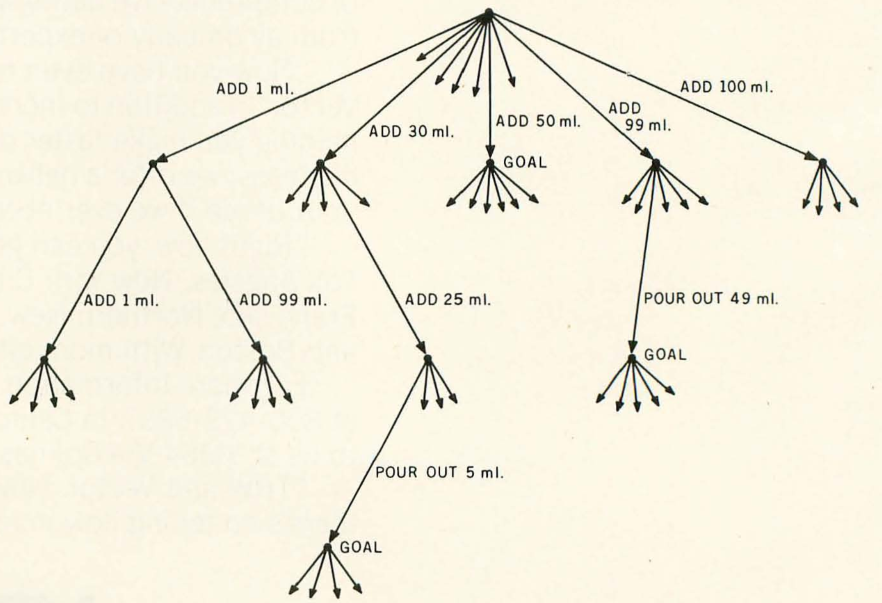

Figure 4: *The "quantization" of a continuous-solution space. Shown is a partial tree for the problem of filling a water glass to a specified mark. It is continuous in that the problem space (the amount of water in the glass) can hold an infinite variety of states (amounts of water). By considering the glass to hold water only in single-milliliter increments, the problem space becomes discrete and finite, and thus can be represented to a computer. Goal nodes exist where the water level matches the mark on the glass.*

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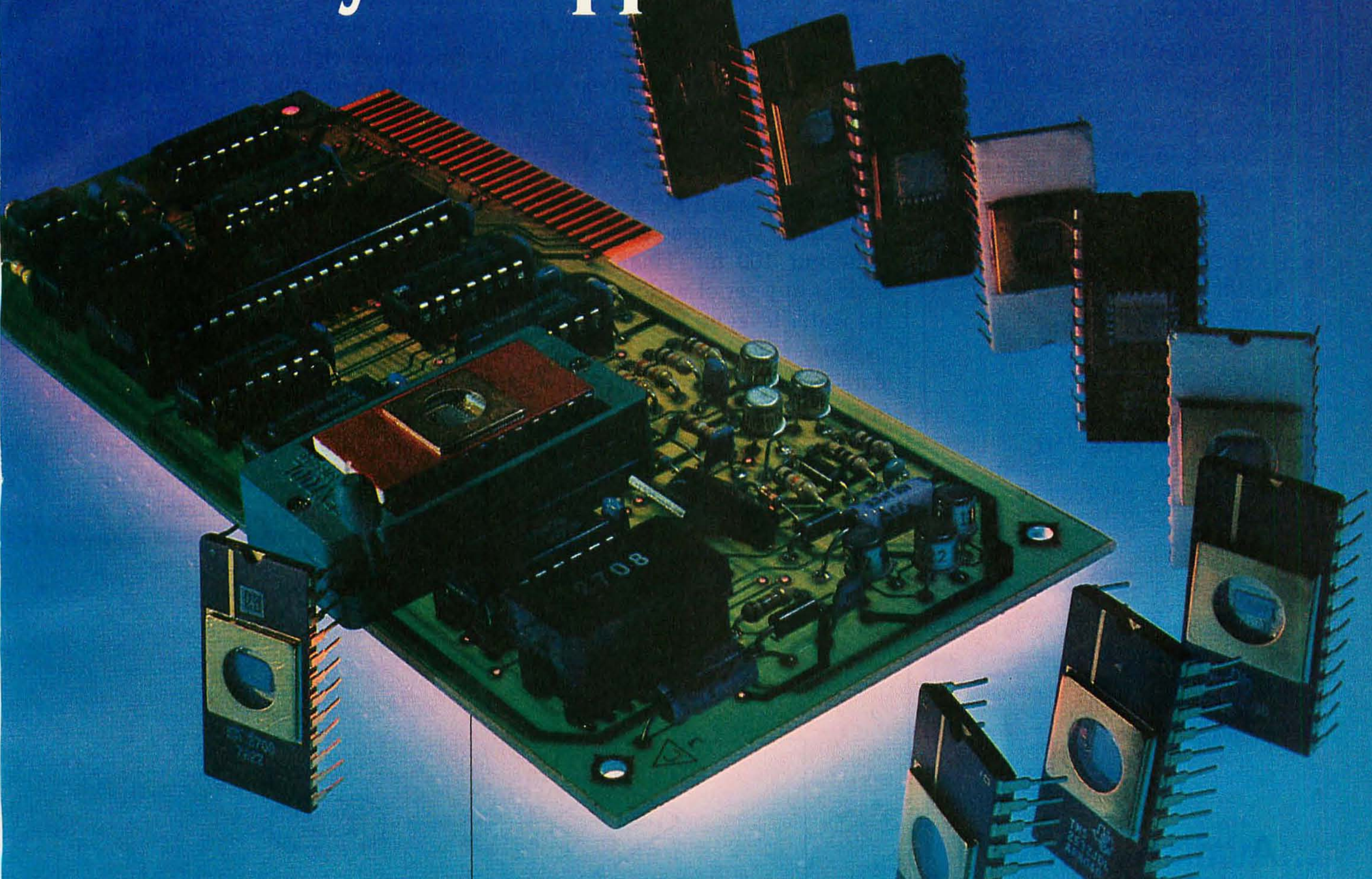

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ml (empty), 1 ml of water, 2 ml, . . ., 100 ml. (Here the word "state" seems more natural than "node"; the latter usually refers to the graphic representation of the problem.)

Time as well as volume must also be quantized, which restricts us to adding or subtracting a given volume of water "at one time." We have 200 possible operators (some of which may be physically impossible for a given state): add 1 ml, pour out 1 ml, add 2 ml, . . . and so on up to add or pour out 100 ml. Finally, the goal node is any set of actions that brings the water level up to the marked line (wherever it happens to be). The state-space tree is large but finite; part of it is shown in figure 4.

The 15-Puzzle

Most of us have played with the 15-puzzle: fifteen numbered squares that slide around in a frame that allows four units on a side. The blocks are given in an arbitrary order and the object is to slide the blocks until, read by row, they are in ascending order with the blank space in the lower right-hand corner. (Mathematician/puzzlist Sam Lloyd made a lot of money betting people they couldn't solve the puzzle. It was a sure bet; with the starting position he used, a solution was impossible.)

We will use the 15-puzzle to illustrate various search methods. The BASIC program SEARCH (see listing 1) will implement different search techniques by changing only one subroutine. It will work for both the 15-puzzle and (for computers with less memory) the order-3 variation: the 8-puzzle. In this article we will use the 8-puzzle for illustration; even

Text continued on page 86

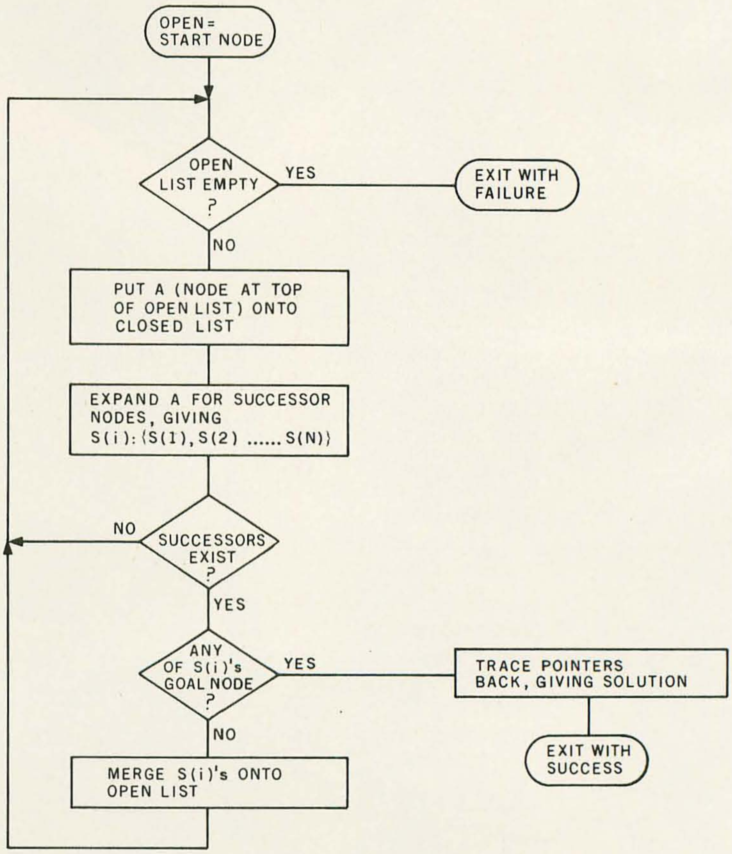

Figure 5: *The basic flowchart used to derive the SEARCH program of listing 1a. This flowchart is a modernized, generalized version of several given by Nils Nilsson in* Problem-Solving Methods in Artificial Intelligence. *The flowchart was written as structured pseudocode (see listing 1b) before becoming the BASIC program SEARCH.*

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Listing 1: *The SEARCH program, written in Applesoft BASIC for the Apple II. Listing 1a gives the program as implemented in BASIC. Listing 2, 3, or 4 must be added for this program to work. The subroutine that starts at line 9900 implements a given search method; all REM (remark) lines can be deleted to reduce program size. The diagnostic message printed by line 177 gives visual feedback on the progress of the program, although it does not give the correct value for the start node (node 1). The structured pseudocode in listing 1b outlines the processes in SEARCH. Line numbers here refer to the "main line" of the program.*

```
1  REM --SEARCH ALGORITHMS AND PGM FOR 15 PUZZLE
2  REM  --GREGG WILLIAMS, BYTE MAGAZINE, POB 432, HANCOCK NH 03449
3  REM
4  REM
5  REM ------ LISTING 1 ------
100  DIM O$(100),O(100),R$(20)
102  DIM A$(4),E$(4,4),F$(4,4),Z(16)
110  REM --INITIALIZE PROGRAM
120  GOSUB 9500
125  REM
130  REM
135  REM --NEXT IS DO-WHILE LOOP:WHILE"OPEN" ARRAY NOT EMPTY AND EXIT
140  REM --VARIABLE="SEARCH"
150  IF E1$ = "EXIT" THEN 495
158  REM
160  REM
165  REM --FIND N1=INDEX OF LOWEST OPEN VALUE
170  GOSUB 9000
175  IF O(N1) >  = 99999 THEN 495
177  PRINT "177-EXPAND NODE ";N1;", ";O$(N1);", VAL=";O(N1)
180  REM
185  REM --PUT NODE TO CLOSED;"SCRATCH" IN OPEN ARRAY
187  REM --  BY GIVING LARGE VALUE
190 C9 = C9 + 1
200 O(N1) = 90000 + O(N1)
220  REM
225  REM
230  REM --UNPACK BOARD POSN AND GENERATE SUCCESSORS IN A$
240 E$ =  MID$ (O$(N1),H1 + 1,L2)
250 E9$ =  MID$ (O$(N1),H1,1)
255  GOSUB 9100
260  REM --NODE # N1 IS PASSED AS ITSELF
265  REM --GENERATE SUCCESSORS
270  GOSUB 9200
275  REM
280  REM
285  REM --EVALUATE EACH FOR GOAL STATUS--G1 NODES WERE GENERATED
287  IF G1 > 0 THEN 295
290  PRINT "290--NO SUCCESSORS, NODE";N1
292  GOTO 470
295 G$ = "NOT GOAL": FOR M1 = 1 TO G1
300  REM --RETURN "GOAL" IF A$(M1) IS GOAL NODE
310  GOSUB 9600
320  IF G$ <  > "GOAL" THEN 380
330 E1$ = "EXIT"
340  REM --SAVE INDEX OF GOAL NODE
360  REM --FOLLOWING IS "ELSE" BRANCH OF 320:G$ NOT = "GOAL"
370  REM --UNPACK BOARD TO E$,F$ ARRAYS
380 E$ =  MID$ (A$(M1),H1 + 1,L2)
390  GOSUB 9100
395  REM --EVAL H-HAT FCN FOR E$, RESULT IN R1
400  GOSUB 9900
410  REM --PUT A$(M1) ON "OPEN" LIST
420 O9 = O9 + 1
430 O$(O9) = A$(M1)
440 O(O9) = R1
450  NEXT M1
460  REM --END OF DO-WHILE LOOP AT 150
470  GOTO 150
475  REM
480  REM -----------------------------------
485  REM --THIS SECTION PRINTS EITHER SOLUTION OR FAILURE MESSAGE
495  IF G$ <  > "GOAL" THEN 540
500  REM --TRACE BACK SOLUTION
510  GOSUB 9800
520  GOTO 550
530  REM --NO SOLUTION FOUND
540  PRINT : PRINT "NO SOLUTION FOUND"
550  PRINT "NODES ON OPEN LIST:  ";O9 - C9
560  PRINT "NODES ON CLOSED LIST:";C9
570  END
8000  FOR I = 1 TO R9
8010  FOR J = 1 TO R9
8020  PRINT F$(I,J);: NEXT J
8030  PRINT " ": NEXT I
8040  RETURN
8890  REM --------------------------------
8895  REM --SUBRTN TO CHECK IF NEW BOARD F$(I,J)
```

Listing 1a continued on page 82

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Listing 1a continued:

```
8900 O3$ = "NOT DUPLICATED"
8905  REM --CHECK THROUGH ALL EXPANDED NODES
8910  REM -- I.E., NODES WITH O(I)>=90000
8915  FOR I = 1 TO O9: IF O(I) < 90000 THEN 8930
8920 F1$ =  MID$ (Q$(I),H1 + 1,L2)
8925  IF F$ = F1$ THEN O3$ = "DUPLICATED" THEN 8938
8930  NEXT I
8935  IF O3$ = "NOT DUPLICATED" THEN 8938
8937  PRINT "8937--CURRENT POSN IS DUPLICATE ***"
8938  RETURN
8985  REM ------------------------------
8990  REM --SUBRTN TO FIND N1 SO THAT O(N1) IS SMALLEST
8995  REM
9000 S1 = 99999:N1 = 1
9005  FOR I = 1 TO O9
9010  IF O(I) >  = S1 THEN 9020
9015 S1 = O(I):N1 = I
9020  NEXT I
9025  RETURN
9035  REM ------------------------------
9040  REM --PACK BOARD F$(N,N) TO STRING F$
9045  REM
9050 F$ = ""
9055  FOR B = 1 TO R9
9060  FOR D = 1 TO R9
9065 F$ = F$ + F$(B,D)
9070  NEXT D
9071  NEXT B
9090  REM ------------------------------
9095  REM --UNPACK STRING E$ INTO ARRAYS E$(N,N), F$(N,N)
9100  FOR I = 1 TO R9
9105  FOR J = 1 TO R9
9110 Q1 = R9 * (I - 1) + J
9115 E$(I,J) =  MID$ (E$,Q1,1)
9120 F$(I,J) =  MID$ (E$,Q1,1)
9125  NEXT J: NEXT I
9130  RETURN
9185  REM ------------------------------
9190  REM   EXPAND CURRENT POSN E$(I,J) WITH DIRECTION E9$,NODE# N1
9195  REM --   GIVING SUCCESSORS IN ARRAY A$(N);N=1 TO G1
9200  FOR I = 1 TO 5
9205  IF E9$ =  MID$ (D$,I,1) THEN 9210
9207  NEXT I
9210 Q9$ =  MID$ (I$,I,1)
9215  REM --Q9$ IS FORBIDDEN DIRECTION TO EXPAND E$
9220  FOR Y1 = 1 TO R9: FOR X1 = 1 TO R9
9225  IF E$(X1,Y1) = "." THEN 9238
9230  NEXT X1: NEXT Y1
9235  REM  --X1,Y1=COORDINATE OF "BLANK" IN PUZZLE
9238 G1 = 0
9240  REM --NEXT IS A LOOP THAT GENERATES 4 POSSIBLE SUCCESSORS
9242 S1 = 1:A9 = 0
9245  IF S1 > 4 THEN 9315
9250  IF  MID$ (D$,S1,1) = Q9$ THEN 9310
9255 X2 = X1 + X(S1):Y2 = Y1 + Y(S1)
9260  FOR I = 1 TO R9: FOR J = 1 TO R9
9265 F$(I,J) = E$(I,J): NEXT J: NEXT I
9270  REM --EXCHANGE SQUARES (X1,Y1) AND (X2,Y2)
9272  IF X2 < 1 OR X2 > R9 THEN 9310
9273  IF Y2 < 1 OR Y2 > R9 THEN 9310
9275 F$(X1,Y1) = F$(X2,Y2):F$(X2,Y2) = "."
9280  REM --PACK NEW BOARD AS NODE IN A$(N)
9285  GOSUB 9050
9287  REM --CHECK FOR DUPLICATES IN Q$
9290  GOSUB 8900
9295  IF O3$ = "DUPLICATE" THEN 9310
9296  REM --NODE=POINTER BACK+DIRECTION+PACKED ARRAY
9297 A9 = A9 + 1
9302  GOSUB 9400
9303 A$(A9) = Q$ +  MID$ (D$,S1,1) + F$
9305 G1 = G1 + 1
9310 S1 = S1 + 1: GOTO 9245
9315  RETURN
9390  REM ------------------------------
9395  REM  --SUBR CONVERTS N1 TO A STRING OF CHARS, LENGTH OUTPUT IN Q8
9397  REM
9400 Q$ =  STR$ (N1)
9410 Q1 =  LEN (Q$)
9420  REM  --ADD LEADING ZEROES TO Q$
9425 Q2 = Q8 - Q1
9430  IF Q2 >  = 0 THEN 9440
9435  PRINT "SIZE ERROR IN 9400--ABORT JOB": END
9440  IF Q2 = 0 THEN 9455
9445  FOR I = 1 TO Q2
9450 Q$ = "0" + Q$: NEXT I
9455  RETURN
9485  REM ------------------------------
9490  REM  --SUBRTN TO INITIALIZE PGM
9495  REM
9500 Q8 = 3:R9 = 3
9505  DATA  -1,0,0,1,1,0,0,-1
9510  FOR I = 1 TO 4: READ X(I),Y(I): NEXT I
9515 D$ = "DLURB":I$ = "URDL"
9520 E9$ = "B"
9523 Q2$ = "1.3426758": GOTO 9535
9525  PRINT : PRINT "ENTER PUZZLE TO BE SOLVED IN ";R9 * R9;" CHARACTERS"
```

Listing 1a continued on page 84

Listing 1a continued

```
9530  INPUT Q2$
9535  IF  LEN (Q2$) = R9 * R9 THEN 9550
9540  PRINT : PRINT "ERROR IN PUZZLE ENTRY - TRY AGAIN."
9545  GOTO 9525
9550 O9 = 1:O(1) = 0
9552 N1 = 1: GOSUB 9400
9553 O$(1) = Q$ + "B" + Q2$
9555  REM  -- ABOVE IS INITIALIZATION OF "OPEN" LISTS, ARRAYS O AND O$
9560  REM  -- NEXT IS INITIALIZATION OF "CLOSED" LISTS--C AND C$ ARE BOTH EMPTY
9565 C9 = 0
9575 H1 = O8 + 1:L2 = R9 * R9
9580 E1$ = "SEARCH"
9585 G$ = "NO GOAL"
9587  RETURN
9590  REM -----------------------------------
9591  REM --SUBRTN TO SEE IF BOARD IS GOAL NODE
9595  REM ---RETURNS G$="GOAL" OR "NOT GOAL"
9600 Q3$ = "12345678."
9610  IF R9 = 4 THEN Q3$ = "123456789ABCDEF."
9615 Q4$ =  RIGHT$ (A$(M1),L2)
9620  IF Q3$ = Q4$ THEN G$ = "GOAL":N6 = O9 + 1
9625  REM --N6=INDEX OF GOAL NODE;=O9+1 BECAUSE O9 POINTS TO LAST
9630  REM --  NODE FILLED; SEE 420-440
9635  RETURN
9685  REM -----------------------------------
9785  REM -----------------------------------
9790  REM --SUBRTN TO TRACE BACK AND PRINT SOLN FROM O$(N1)
9795  REM
9800 R1 = 0
9805  REM --DO UNTIL POINTER = "B"
9810 Q$ =  MID$ (O$(N6),O8 + 1,1)
9815  IF Q$ = "B" THEN 9820
9817 R1 = R1 + 1:R$(R1) = Q$
9820 Q1$ =  LEFT$ (O$(N6),O8)
9825 N6 =  VAL (Q1$)
9830  IF Q$ <  > "B" THEN 9810
9835  REM  -- DONE; PRINT VALUES OF R$ FROM R1 TO 1
9840  IF R1 <  = 0 THEN  PRINT : PRINT "ZERO ERROR IN BACKTRACKING": GOTO 9880
9845  PRINT : PRINT "SOLUTION IS ";
9850  FOR N = R1 TO 1 STEP  - 1
9855  PRINT " ";R$(N);
9860  NEXT N
9865  PRINT : PRINT : PRINT R1;" STEP";
9867  IF R1 > 1 THEN  PRINT "S";
9869  PRINT : PRINT
9880  RETURN
```

(1b)

```
120   EXIT = no, GOAL = no part of initialization routine
      OPEN = <start node>

150   do while OPEN not empty and EXIT = no
170       :A = top node in OPEN
190       :put A from OPEN to CLOSED list
270       :expand A giving successors A(N)

287       :if successors exist
295       :    :for each successor
310       :    :    :evaluate successor for goal status
320       :    :    :if node-is-goal
330       :    :    :    :set G = index of good node, GOAL = Yes
          :    :    :    :set EXIT = yes
                         else
400       :    :    :    :calculate "value" of node
420       :    :    :    :merge node and value into OPEN list
          :    :    :    end if
450       :    :    :end of for-loop
          :    :end if
470       :endwhile

495   if GOAL = yes
510       :find solution by tracing nodes back from G
          :print full solution
        else
540       :print failure message
        endif

570   end program
```

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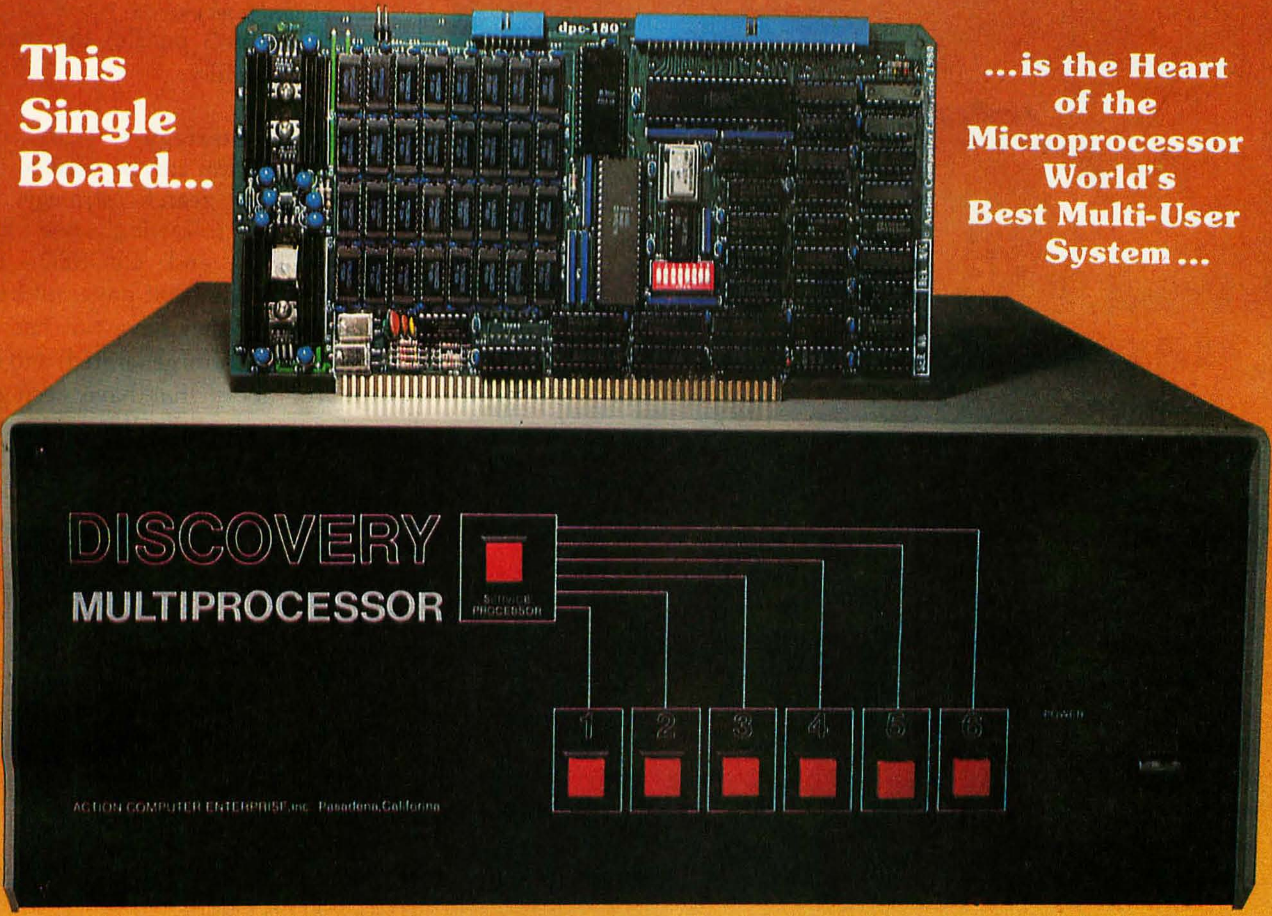

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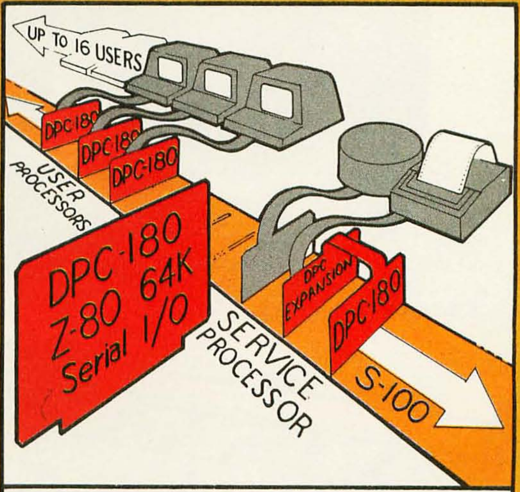

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Text continued from page 78:
with this 3-by-3 puzzle, the search tree grows rapidly.

Elementary Strategy

A certain form can be used to implement any search strategy. It assumes the following: two lists called OPEN and CLOSED, the former for nodes that have not been expanded (ie: that have not had all possible successors generated) and the latter for nodes that have been expanded; an algorithm for generating all legal successors; and an algorithm for determining whether or not a node is a goal node. One final algorithm, $\hat{f}$, which implements the given search technique, provides a function that is used to order the members of the OPEN list to determine which node is to be expanded next.

The general algorithm is given in flowchart form in figure 5. It may be described as follows:

1. Place the start node on OPEN. CLOSED is empty.
2. If OPEN is empty, no solution exists; exit with failure.
3. Otherwise, let A equal the node at the top of the OPEN list. Take A off the OPEN list and put it on the CLOSED list.
4. Find all possible successors of A, named S(1), S(2),...S(N).
5. If there are no successors (N=0), go to 2.
6. Check the successors for goal status. If one is a goal, go to 8.
7. Calculate the $\hat{f}$-values of each successor and merge the nodes into the OPEN list so that the OPEN nodes are sorted in ascending $\hat{f}$-values. Also, place a pointer in each successor node that points back to the parent node A. Go to 2.
8. Trace the goal node through the pointers to the start node. This sequence, reversed, is the solution.
9. Exit with success.

The method described above is exhaustive and complete—that is, it always terminates. If it returns with an "exit with failure," it is because all nonterminal nodes have been expanded without finding a goal.

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Overview of the SEARCH

A complete explanation of the SEARCH program would be unreasonably long, so I am including only those points that will save the reader from puzzling through the mechanics. All comments refer to the 15-puzzle version. (Conversion to the smaller 8-puzzle is achieved by changing the value of R9 to 3 in statement 9500 of listing 1.)

- The program in listing 1a is equivalent to the structured pseudocode of listing 1b and the flowchart of figure 5.
- The major variables used in the program are given in table 1.
- The body of the SEARCH program (which corresponds to the pseudocode algorithm) is contained in lines 120 through 570; the subroutines used are listed in table 2.
- Instead of new nodes being sorted into the OPEN list, they are added at the end of the list and given an ordering value. Instead of expanding the top node on the list, the node with the lowest ordering value (in array O (N)) is expanded. This eliminates an unnecessary sort in the program.
- The program has eliminated the need for a CLOSED array by tagging nodes to be closed with an O-value of greater than 90,000. The number of nodes that has been closed is in C9.
- The SEARCH program assigns variable names to certain constants within the program so that the program can be altered to fit computers of different sizes by changing only a few statements. See variables L2, O8, and R9 in table 1.
- The complete representation of a node in this program includes variables O(N) and O$(N), where N is the number of the nodes. O(N) is the orderings value relative to the

Variable Name	Use
A$(N)	Array of successors generated by current board position E$(I,J); see A9.
F$(N)	String of characters equivalent to board F$(I,J); see subroutine at line 9050.
O(N)	Ordering value of node N on OPEN list; node is considered to be on CLOSED list if O(N) > 90,000.
O$(N)	Body of node N on OPEN list; see text.
R$(N)	Letters that, when arranged in reverse order, give the solution to the puzzle; see R1.
X(N), Y(N)	Increments in *x*- and *y*-position to cause a unit move in direction N, N = 1,2,3,4.
E$(I,J)	Representation of current node in expanded form; I, J vary from 1 to R9.
F$(I,J)	Scratch pad board used to generate successors to board E$(I,J).
A9	Number of nonduplicate successors generated; see A $(N).
C9	Number of nodes that have been tagged as closed, see O(N).
D$	The characters of D$ represent the possible moves in the puzzle (down, left, up, right) and their orderings (eg: move 2 = MID$(D$,2) = "L" = left; move 5, B, stands for "beginning" and applies only to the start node).
E9$	Direction used to get to current node from its predecessor.
G$	Indicates whether or not A$(MI) is a goal node.
G1	Number of successors generated before check for duplicate nodes.
H1	(Index of first character of game in O$(N)) minus 1; used to index the L9 characters of the board.
L2	Number of characters in current board; =9 for order-3 board, =16 for order-4 board.
N1	Index of O(N) giving smallest ordering value; node N1 will be expanded next.
O7	Maximum size of arrays O(N), O$(N).
O8	Number of digits in O$(N) pointer to its predecessor; set to 3, but, by expanding, can be used to process larger search.
O9	Number of nodes (both open and closed) on O$(N) list; next new node will be placed in O$(O9 + 1).
O9$	Direction that backtracks from current node to predecessor; see text.
R1	Number of steps to solution of puzzle; see R$(N). Also, value returned by subroutine at 9900.
R9	Rank of problem; set to 3 for order-3 board, to 4 for order-4 board.
S1	Current smallest ordering value of array O(N), S1 = O(N1).

Table 1: *Major variables used in the BASIC program SEARCH (see listing 1).*

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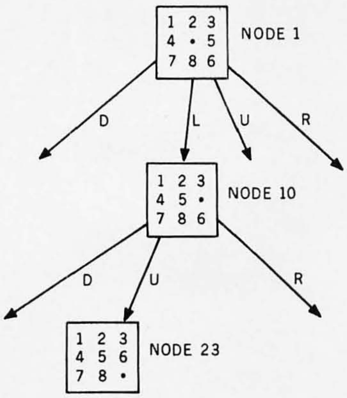
other nodes; O$(N) contains three things: the direction (U, D, R, or L) that transforms the predecessor of O$(N) to O$(N), an O8-digit pointer giving the node number of O$(N)'s predecessor node, and a string of L2 characters that describes the "board" of node N in compressed form. (See figure 6 for further details.)

- For any node not the start node, it is always possible to eliminate one of the legal "next moves." For example, if O(N1) generates O(N2) with a move of D (down), we can forget about generating the successor of O(N2) that uses the move U (up), because the result will be the same board as in node N1 (which has already been expanded). In the SEARCH program, this is done by matching the "direction" of the current node in D$ with its corresponding letter in I$ (I$ is a mnemonic for "inverse"); this second letter is then ignored in expanding the current node (see the subroutine of 9200).
- It is possible for a series of moves to come back to a previously expanded node (this means that the state space for the 15-puzzle is a graph, not a tree). For this reason, the possible successors generated in lines 9240 through 9310 (subroutine 9200) are checked for duplication (subroutine 8900, used at line 9290).
- Each of the four possible moves in the 15-puzzle is associated with a number between one and four (1 means the tile moves down, 2 indicates the tile moves to the left, 3 means the tile moves up, 4 means the tile moves right). Variables that use this numbering are X(N), Y(N), D$, and I$.
- Within the character representation board, the position with no tile is represented by a period.
- The SEARCH program was run on an Apple II with 48 K bytes of memory, and it should run without modification on the Commodore PET, the Radio Shack TRS-80 Model I Level II or Model III, or any other computer that uses Microsoft BASIC. The program is written so that all REM lines can be deleted without affecting the program's performance.

Exhaustive Tree Searching

The first method of systematically searching a tree can be described as follows: expand the start node, recording all the successor nodes (which are of depth one); if none of the nodes are goal nodes, expand *all* depth-one nodes, giving depth-two

(6a)



(6b)

O(10) = 5   O$(10) = "L 001 12345.786"
O(23) = 3   O$(23) = "U 010 12345678."

Figure 6: *Representation of the 8-puzzle within the program SEARCH. A node is represented in the program as two variables. One is O(N), the ordering value of node N in the tree. The other is O$(N), a string that has the following:*

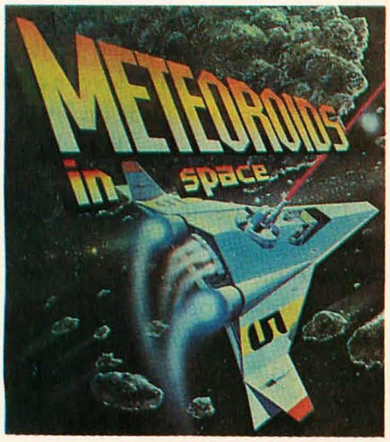
- *the direction used to get from N's parent node to N*
- *the node-number of N's parent node (linking N back to the start node)*
- *the board position for node N, written by rows*

Figure 6a shows part of a hypothetical tree; figure 6b shows how nodes 10 and 23 are represented within the program.

Entry Point	Use	
8900	Input:	Board F$(I,J), array O$(N)
	Process:	Determine if board F$(I,J) has already been expanded.
	Output:	Q3$ = "DUPLICATED" or "NOT DUPLICATED."
9000	Input:	Array O$(N), O9
	Process:	Find smallest value in array.
	Output:	Index N1, value S1 such that S1 = O(N1) is smallest value in O(N).
9050	Input:	Board F$(I,J)
	Process:	Compress to a row-major string of characters.
	Output:	F$ = String of L2 characters.
9100	Input:	String E$
	Process:	Unpack string to board E$(I,J), F$(I,J).
	Output:	Identical boards E$(I,J), F$(I,J).
9200	Input:	Board E$(I,J), node number N1, direction E9$.
	Process:	Generate up to three legal successors of board (which is derived from node N1), eliminate nodes already expanded, build full node (direction + pointer + board) for each successor.
	Output:	Table of successors A$(N), A9.
9400	Input:	Number N1, desired length O8.
	Process:	Convert N1 to a string; strip off the leading blank, fill with leading zeroes.
	Output:	String Q$ that "looks like" N1.
9500	Initialization routine; includes entry of puzzle to be solved.	
9600	Input:	Node A$(M1), rank of problem R9.
	Process:	Extract compressed board from node, compare to goal node.
	Output:	G$ = "GOAL" or "NOT GOAL".
9800	Input:	Goal node O$(N1).
	Process:	Trace through pointers back to start node, collecting "direction letters" in R$(N).
	Output:	Print (R$(R1), R$(R1 − 1), ..., R$(1)) − solution to puzzle.
9900	Input:	Node O$(M1) to be added to list, list O(N) (and other variables depending on method).
	Process:	Adjustment of values in O(N); computation of ordering value for node M1, placed in R1, so that node M1 will be correctly inserted into OPEN list with a correct ordering value.
	Output:	This is the subroutine implementing a given search algorithm.

Table 2: *A description of the subroutines used in SEARCH.*

our first name is Quality



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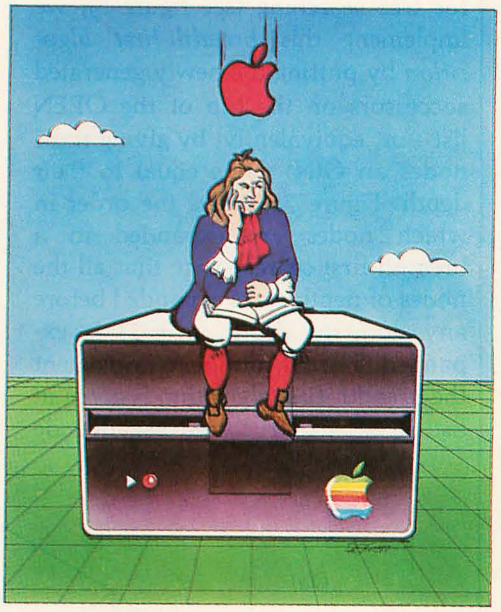

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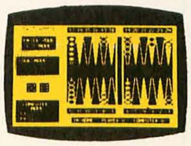

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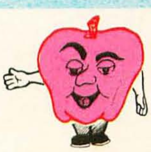

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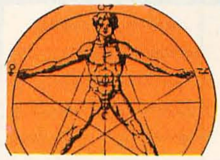

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nodes; repeat this process until a goal node is found or until no unexpanded successor nodes can be found.

In terms of the overall algorithm for tree searching (see figure 5), we implement this *breadth-first algorithm* by putting the newly generated successors on the top of the OPEN list—or, equivalently, by giving these nodes an O(N) value equal to their depth. Figure 7a shows the order in which nodes are expanded in a breadth-first search; note that all the nodes of depth n are expanded before any node of depth $(n + 1)$ is expanded. The subroutine to implement the breadth-first algorithm is given in listing 2a; its structured pseudocode equivalent is:

9900 value of node returned,
     R1 = value of parent
     O(N1) + 1

In a breadth-first search, making the "value" of any node equal to its depth will cause all nodes of level n to be expanded before any node on level $n + 1$ (with "value" $n + 1$). In line 9900, the value 90000 is subtracted because, by this time, the parent node O(N1) has been "marked" as being closed by adding 90000 to it.

An alternate approach to tree searching is the *depth-first algorithm*. In this method, we repetitively ex-

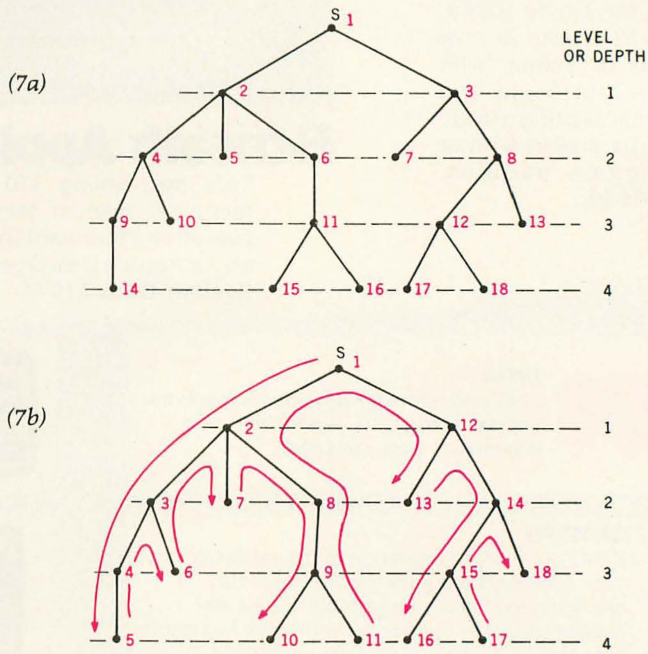

Figure 7: *Order of expansion by three exhaustive-search algorithms. The numbers to the right of each node show the order in which the tree is expanded. Figure 7a, the breadth-first search, is examined laterally, one level at a time; figure 7b, the depth-first search, takes a "walk" around the edges of the tree (as shown by the colored arrows); figure 7c, the limited depth-first search, combines properties of both types of search. These searches can be tried by installing the routines in listings 2, 3, or 4 in the SEARCH program (listing 1).*

pand the successors of a given node (until no such node can be further expanded) before we start to expand the next node of the same depth; that is, we expand down the tree instead of across it, and are, in essence, generating and expanding the terminal nodes from left to right. Figure 7b shows the order in which tree nodes are expanded in a depth-first search; the subroutine to be inserted into SEARCH is given in listing 3. Its pseudocode equivalent is:

```
9900  value of node returned
      R1 = value of parent
      O(N1) - 1
```

In a pure depth-first search, the node just generated should be expanded before any other node already on the OPEN list from past expansions. A good solution is to let the "value" of the successor node be one less than that of the parent. Since the subroutine at 9900 chooses the node with the smallest O array value, this scheme forces the order of expansion just described.

Putting the depth-first algorithm to work, we find that it seemingly generates nodes without end—but without making a practical attempt at moving toward a goal node (except when one happens to be on the leftmost side of the tree). The handicap of the depth-first algorithm is that it will search to the end of a given branch before returning to shallower levels. Because most trees extend to a large, if not an unbounded, depth (whereas a goal node usually exists at a shallower level), the depth-first search is usually inferior to the breadth-first search: the former sweeps up and down the entire length of the tree from left to right, whereas the latter scans uniformly across each level of the tree from top to bottom,

Listing 2: *Subroutine to implement a breadth-first search strategy.*

```
10 REM    --------- LISTING 2 ---------
9890  REM  -- SUBRTN TO COMPUTE H-HAT; BREADTH-FIRST SEARCH
9895  REM  -- RESULT R1=VALUE OF PARENT+1
9900 R1 = (O(N1) + 1) - 90000
9905  RETURN
```

Listing 3: *Subroutine to implement a pure depth-first search strategy.*

```
9890  REM   --------- LISTING 3 ---------
9895  REM  -- SUBRTN TO COMPUTE H-HAT; PURE DEPTH-FIRST SEARCH
9900 R1 = (O(N1) - 90000) - 1
9905  RETURN
```

Listing 4: *Subroutine to implement a limited depth-first search strategy.*

```
9885  REM   --------- LISTING 4 ----------
9890  REM  -- SUBRTN TO COMPUTE H-HAT BY LIMITED DEPTH-FIRST SEARCH
9895  REM  -- VALUE RETD=R1; LIMIT OF DEPTH=R3
9900 R3 = 3
9905 R1 = (O(N1) - 90000) - 1
9910  IF R1 =  - R3 THEN R1 = 0
9915  RETURN
```

usually first encountering a goal node at a shallow level.

The *limited depth-first algorithm* (see figure 7c and listing 4) can be explained as follows. Choose an arbitrary depth, *n*; do a depth-first search, rejecting (for the moment) all nodes of depth *n* or greater. If this does not turn up a goal node, do a depth-first search of the previously rejected nodes, rejecting all nodes of depth 2*n* or greater. Repeat this process until a goal node is found or the tree is exhausted. This is summarized in the pseudocode:

```
9900  R3 = depth of each "layer" of
      search
9905  value of node returned,
      R1 = value of parent
      O(N1) - 1
9910  if "value" to be returned is
      equal in magnitude to R3 reset
      value to be returned = 0 endif
```

The "value" returned will be zero or negative. This search limits itself to depth R3 at a time by setting a node on the edge of the current level to the highest possible value, zero, so that it will be expanded only after the current layer has been expanded to the edge. The value R3 could be placed within the initialization subroutine of 9500.

The limited depth-first search lessens the disadvantages of the pure depth-first search by providing for an eventual exhaustive search of the lower level of the tree. But it is also a compromise: if a goal node is located deep and on the left-hand side of a tree, this node will be more quickly found by the pure depth-first search than by the limited depth-first search. (In general, the effectiveness of both depth-first searches is extremely dependent on the left-right position of a goal node within the tree.)

Notes on Experimentation

We now have the tools with which to examine the exhaustive search algorithms. The BASIC program SEARCH (when fitted with the appropriate subroutine at 9900) will ask for the beginning puzzle (given row by row, with A through E representing 10 through 15 in the order-4 version only, and a period representing the space in the puzzle), list nodes as they are expanded and generated, and print out the solved puzzle. If you want to avoid typing in a puzzle every time you run the program, add the following lines:

```
9521  Q2$ = "<puzzle to be
      entered>"
9523  GOTO 9550
```

My observations and experiments are based on the sample 8-puzzles given in figure 8; a given puzzle will be referred to by its row and column number in this figure. Note that the row number is the number of moves in the solution of the puzzle and that a given puzzle is a subproblem of every puzzle below it and in the same column.

Table 3 gives data on selected puzzles using the breadth- and limited depth-first algorithms. Remember that closed nodes are those that have been expanded for successors and open nodes are those that have been

Text continued on page 98

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(3a)

Puzzle	Solution	#Open	#Closed	Total
(1,1)	L	3	1	4
(1,2)	U	3	1	4
(2,1)	UL	7	4	11
(2,2)	LU	6	3	9
(2,3)	LL	4	3	7
(3,1)	LUL	9	8	17
(3,2)	ULU	7	6	13
(3,3)	ULL	10	9	19
(4,1)	DLUL	12	11	23
(4,2)	LULU	10	9	19
(4,3)	RULL	16	21	37

(3b)

Puzzle	Solution	#Open	#Closed	Total
(1,1)	L	3	1	4
(1,2)	U	3	1	4
(2,1)	UL	11	12	23
(2,2)	LU	8	7	15
(2,3)	LL	10	9	19
(3,1)	LUL	11	13	24
(3,2)	ULU	9	7	16
(3,3)	ULL	12	17	29
(4,1)	DLUL	9	8	17
(4,2)	LULU	7	6	13
(4,3)	RULL	16	21	37

(3c)

Puzzle	Solution	Depth (n)	#Open	#Closed	Total
(2,2)	LU	2	6	3	9
		3	6	5	11
		4	8	7	15
		5	12	11	23
(2,3)	LL	2	4	3	7
		3	6	5	11
		4	10	9	19
		5	12	17	29

Table 3: *Experiments with SEARCH. In the breadth-first search (3a), "# Open" refers to the number of nodes created but not yet expanded. "# Closed" is the number of nodes that have already been expanded. Since the breadth-first algorithm searches uniformly down the tree from the start node, it is the most reliable of the exhaustive search methods.*

The limited depth-first search (3b), with depth n=4, shows that for all puzzles on level four, the number of nodes that this algorithm generates is the same or less than the breadth-first search. By varying the cutoff depth, n, this algorithm does a depth-first search in "layers" (see 3c), each layer being n nodes deep. As n becomes greater than the number of moves in the solution (in this case, two), the algorithm more closely resembles a pure depth-first search in its inefficiency.

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Text continued from page 95:
generated but not yet closed (expanded); thus, the total number of nodes generated by an algorithm is the sum of its open and closed nodes.

Also remember that the SEARCH program generates successors by expanding in the following order: *down, left, up, right*. Although this is less important for more advanced searches, it is extremely important when analyzing exhaustive searches.

Observations and Questions

Please consider the following questions before you read the answers on page 102. On the breadth-first search:

• Note that the number of nodes expanded to get a solution varies with the directions used in the solutions; "downs" and "lefts" tend to make the solution shorter, while "ups" and "rights" make it longer. Compare the puzzle (2,3) with the puzzle at (2,1), and puzzle (4,2) with (4,3).

• (Question 1) How is this tendency reflected in the number of nodes on the closed list? (Consult the text box, "Answers," on page 102.)

• (Question 2) Then why does puzzle (3,2), with solution LUL, generate more nodes than puzzle (3,1), which has solution ULU? Aren't L moves expanded before U moves?

• Notice that both puzzles (1,1) and (1,2) have the same number of open and closed nodes, even though the solution, L, in (1,1) precedes the solution, U, in (1,2). This is because the SEARCH program generates *all* the valid successors of the node being expanded before evaluating them for goal status.

• (Question 3) I noticed a curious fact while examining the solution of two puzzles, one of which is a subproblem for the other: the subproblem generates a node that the larger problem does not. Run puzzles (2,1) and (3,1) using the breadth-first subroutine and list the nodes generated. Where is the node in question? Why is it generated in (2,1) and not in (3,1)?

On the depth-first search:

• You will probably find that you run out of memory (or patience) before you get a solution from the depth-first algorithm. This is because the algorithm first dives to the bottom of the tree, and that bottom is deep, even for a puzzle as small as the order-3 8-puzzle. Try experimenting with the depth-first algorithm, using the SEARCH program set to handle the order-2 puzzle.

On the limited depth-first search:

• Table 3b shows the results from the solution of the same puzzles, (2,2) and (2,3), using different cutoff depths (variable D3 in line 9900). Since both puzzles are solved in two moves, the cutoff depth simply determines how far down the search will

Text continued on page 102

Goal Node	1 2 3 4 5 6 7 8 .		
Row Number			
(1) One move away	1 2 3 4 5 6 7 . 8	1 2 3 4 5 . 7 8 6	
(2) Two moves away	1 2 3 4 . 6 7 5 8	1 2 3 4 . 5 7 8 6	1 2 3 4 5 6 . 7 8
(3) Three moves away	1 2 3 . 4 6 7 5 8	1 . 3 4 2 5 7 8 6	1 2 3 . 5 6 4 7 8
(4) Four moves away	1 2 3 7 4 6 . 5 8	. 1 3 4 2 5 7 8 6	1 2 3 5 . 6 4 7 8

Figure 8: *A table of 8-puzzles used in the text. Ignoring the row with the goal node, each puzzle is referred to by its row and column numbers (eg: the rightmost puzzle in the row labeled "two moves away" is puzzle (2, 3). Notice how puzzles in the same column are related to each other: each puzzle is a subproblem of the puzzle that appears directly below it.*

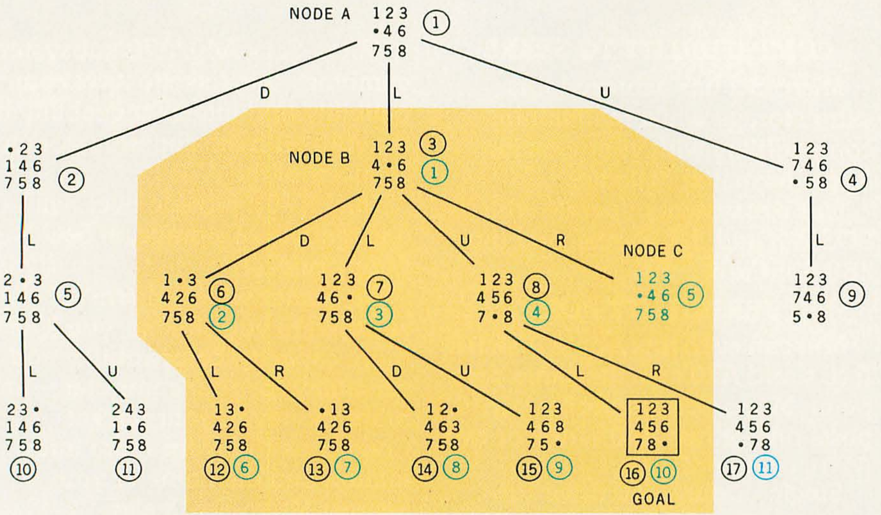

Figure 9: *Solution of puzzle (3, 1) by the breadth-first algorithm. The tree is a partial tree carried out only far enough to reach the goal node (shown in the bottom row). The circled numbers in black indicate the order in which nodes are expanded to solve the puzzle. The node labeled B is the start node of puzzle (2, 1), a subproblem of puzzle (3, 1); circled numbers in color indicate the order in which nodes are expanded to solve puzzle (2, 1).*

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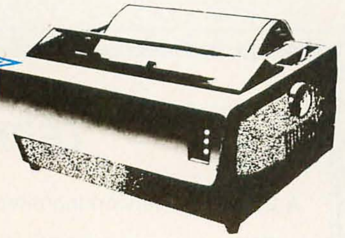

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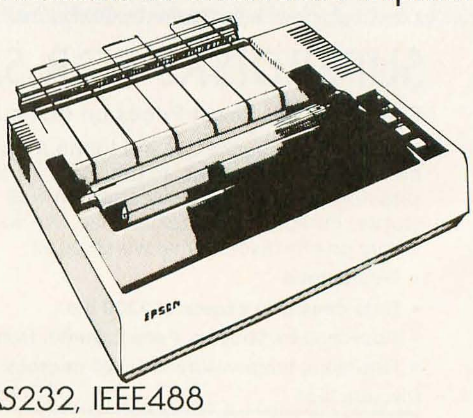

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Text continued from page 98:

go before returning to shallower depths.

• The definition of a limited depth-first search of level n is that it expands $n - 1$ levels at a time, generating the current level n nodes but not immediately expanding them. Therefore, such a search is most efficient when the level of the search is equal to the number of moves in the solution: the search drops down the left-most side of the tree, stops at level n, and scans across the n-level subtree from left to right.

• I made an unexpected discovery: the limited depth-first search is guaranteed to expand less than or the same number of nodes as the breadth-first search *when the depth of the search (n) is equal to the number of steps (s) in the solution*. An intuitive proof of this can be seen from the example of figure 11. Also, it can be inferred that the two searches are

Answers

1. If a given step of a solution is one of the last to be expanded (say, up or right), then the breadth-first search will first expand in other, nonproductive ways (remember the order: down, left, up, right). It is the expansion of these nodes that increases the number of nodes on the closed list.

2. Yes, L moves are expanded before U moves, but an analysis of the situation shows that the order in which nodes are expanded (down, left, up, right) is only one of several factors influencing the number of nodes expanded by a breadth-first search. Refer to figures 9 and 10. If you count the number of terminal nodes (which are open—yet to be expanded) and nonterminal nodes (representing closed, or already expanded nodes), you will find that the numbers agree with those listed in table 2a. (Remember to count the start node as being closed; also, for the moment, ignore node C in figure 9.)

The two trees are identical in number and distribution of nodes through rank two (ie: in nodes 1 through 9). The overwhelming reason that puzzle (3,1) expands more nodes than puzzle (3,2) is that the former has to expand more level-two nodes to get to the goal node. Why is this? Because, from node 3 (in both trees), the path leading to the goal node in puzzle (3,2)—the L branch in figure 10—is expanded before the corresponding path—the U branch in figure 9—is expanded. Here the single L in the solution of puzzle (3,2) is more important than the two L s in the solution of (3,1) because it prevents the expansion of several "fertile" nodes (nodes six and seven in figure 9) on the next-to-last level.

We should not, however, be tempted to generalize. The factors influencing the number of nodes generated are so interdependent that it is impossible to evaluate their relative strengths outside the context of a specified example.

3. Refer to figure 9. The entire tree (minus node C, in color) is the solution tree for puzzle (3,1). The nodes in the colored box (including node C) are the solution tree for puzzle (2,1).

Now the reason for the fact that node C is generated only by (2,1) becomes clear. When node B is a start node, all four directions generate valid successors, but when node B is generated by starting node A in puzzle (3,1), the SEARCH program rightly denies node C successor status because the direction of the move from B to C undoes the move directly before it, A to B. Here again, the interaction of forces in the algorithm create unexpected but correct results.

4. The two important factors in this situation are the depth and the "leftness" of the goal node. Because the limited depth-first algorithm scans from left to right, the "leftness" of the goal node is the more important factor: a node midway in the tree but closer to the left edge of the tree than another node (which is further down), will be expanded first. This is also true for a pure depth-first search.

5. A limited depth-first search of order one is equivalent to a breadth-first search; that is, because $n = 1$, the algorithm does an exhaustive search of the tree one level at a time. Numbering the nodes of a tree according to the limited depth-first algorithm will demonstrate the equivalence of the two forms.

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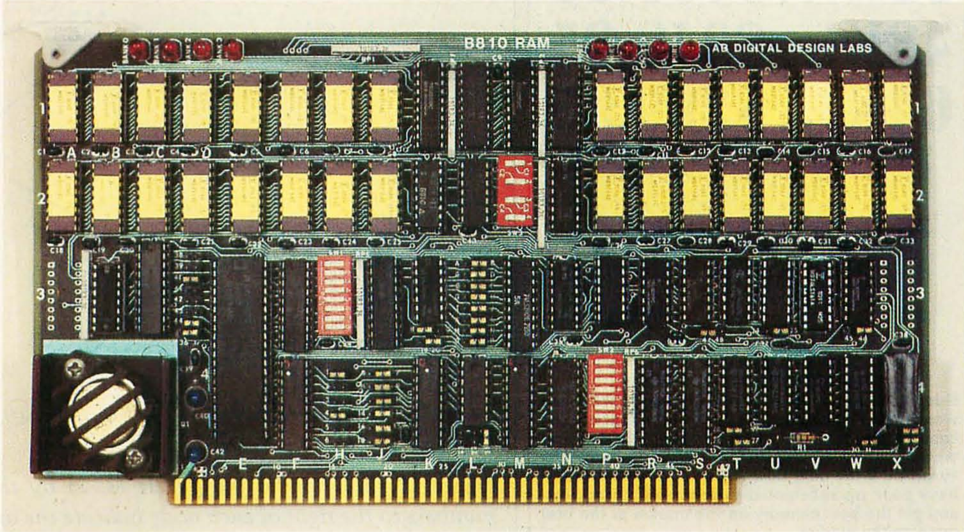

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approximately equivalent in efficiency when n is only slightly larger than s.

- (Question 4) In a limited depth-first search of level n on a puzzle with a solution of n moves, what are the two most important characteristics (in terms of the location of the goal node) that influence the solution time of the puzzle? Which is more important?
- With limited depth-first searches of depth greater than the number of

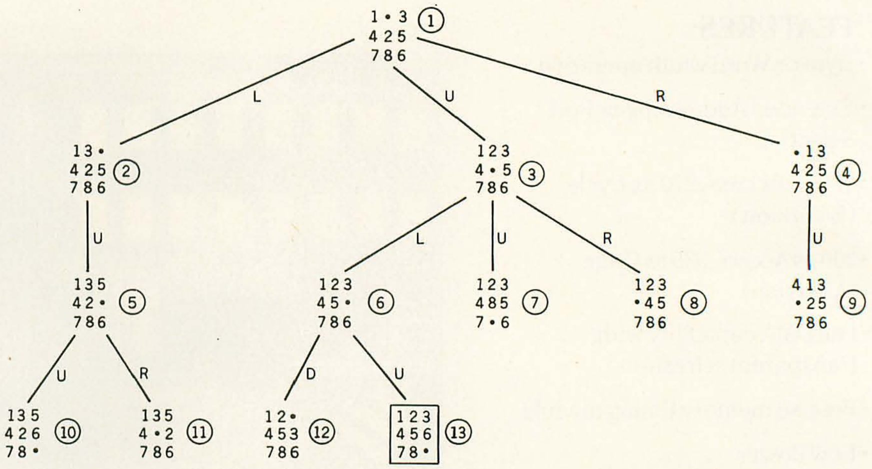

Figure 10: *Solution to the puzzle (3, 2) by the breadth-first algorithm. The circled numbers to the right of each node indicate the order in which they are expanded. Nodes 8 through 13 (six nodes) are "open" (ie: they have not yet been expanded), whereas nodes 1 through 7 are "closed."*

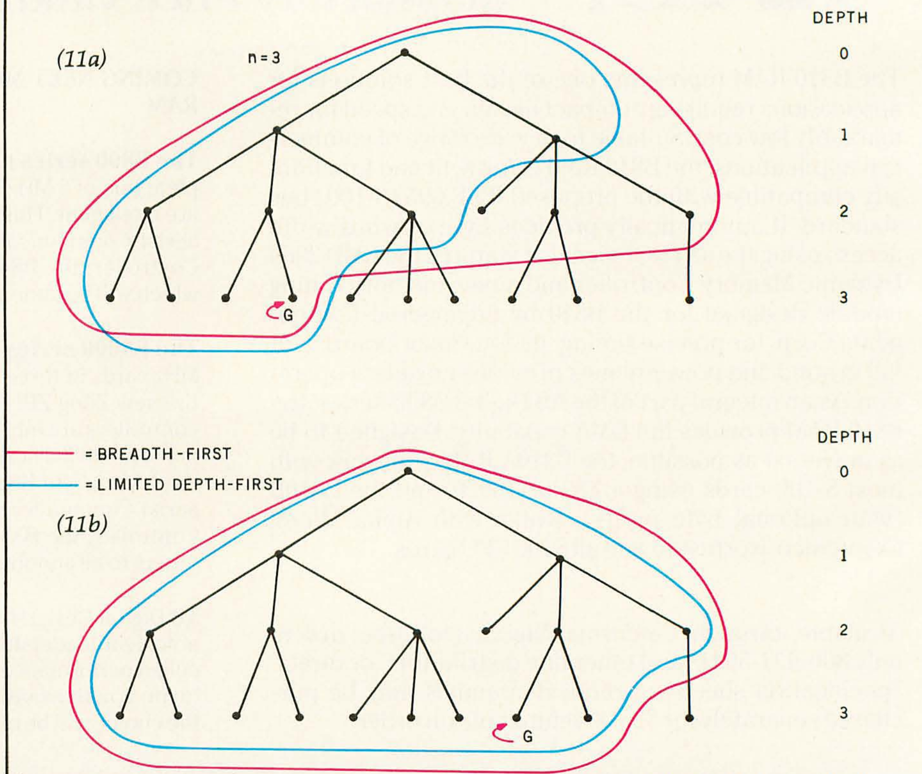

Figure 11: *A comparison of search efficiency. The limited depth-first search always produces the same or fewer nodes than the breadth-first search, when the depth of the search is equal to the depth of the goal node. An example of the efficiency of the limited depth-first search is shown in figure 11a, where the breadth-first search (indicated in color) has produced more nodes. In figure 11b, the two types of searches produce an equal number of nodes, using the same partial tree but a different goal node. The breadth-first search must always expand the entire tree to depth $n-1$, whereas the limited version may not, depending on the location of the goal node.*


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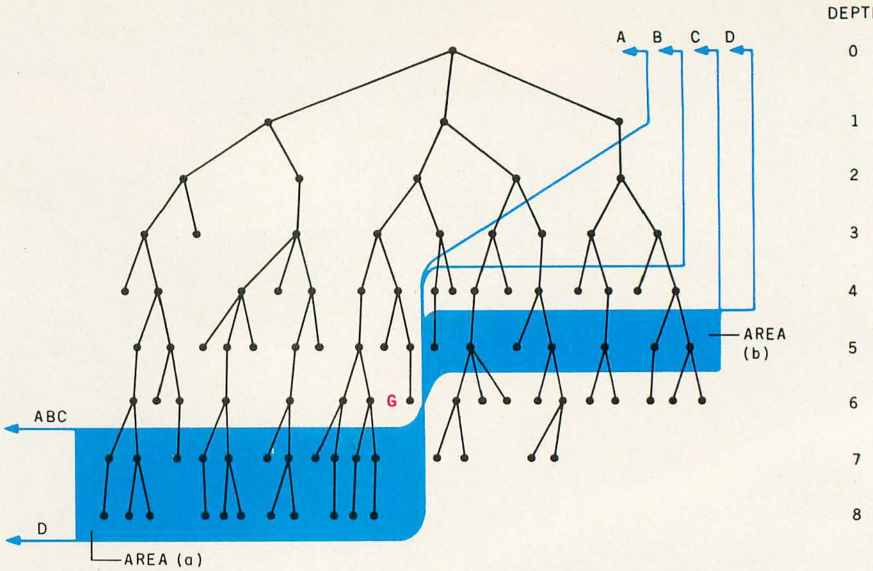

Figure 12: *A comparison of four exhaustive searches. Given the partial tree with goal node on level six, the four lines A, B, C, and D delineate the nodes expanded by the following searches:*

A limited depth-first search, with n=s=6
B limited depth-first search, with s an even multiple of n (s=6, n=3)
C breadth-first search
D limited depth-first search with s not an even multiple of n (s=6, n=4)

The worst case for the limited depth-first search, given by D, expands more or fewer nodes than the breadth-first search, C, depending on whether area a or area b has more nodes.

moves in the problem solution ($n > s$), the number of nodes expanded increases with the difference between the two (see the results of table 3b).

- When the depth of the search is less than the number of moves in the solution ($n < s$), two cases occur. If s is a multiple of n, the efficiency of the search is between that of a breadth-first search and a limited-depth search with $n = s$ (as illustrated in figure 12). If, however, s is not a multiple of n, the result is mixed. The depth-first search will go several levels deeper than the level of the solution and may be better or worse than a breadth-first search depending on the number of nodes expanded past level s and the number of nodes expanded in the breadth-first search that are not expanded in the limited depth-first search (see figure 12).
- (Question 5) A depth of one ($n = 1$) gives a special case of the limited depth-first search. What is another name for this search?

Conclusions

We've covered quite a bit of material in this article, including an introduction to tree- and graph-searching terminology, a definition of the finite-state representation of a problem, the general-purpose search algorithm implemented in the BASIC program SEARCH, and three exhaustive-search algorithms. In most cases, a breadth-first search is the best of the three, but in some cases it can be improved upon by the limited depth-first search.

Part 2 will deal with heuristic algorithms that estimate the "worth" of a given node in order to arrive at a guaranteed solution without performing an exhaustive search. ■

References

1. Nilsson, Nils J. *Problem-Solving Methods in Artificial Intelligence*. New York: McGraw-Hill, 1971. An excellent book on all aspects of this subject as well as the related topics of problem reduction, theorem-proving, and the searching of game trees.
2. Winston, Patrick Henry. *Artificial Intelligence*. Reading MA: Addison-Wesley, 1977. A good overview of artificial intelligence with one section devoted to tree searching.

Book Review

Turtle Geometry

by Harold Abelson and Andrea A diSessa
MIT Press,
Cambridge MA, 1981,
478 pages, $20.00

Reviewed by
W Lloyd Milligan
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Imagine four turtles, each sitting at one corner of a square. At the same moment, each turtle begins to crawl in a clockwise direction toward its nearest neighbor. They continue crawling at the same speed toward one another until they meet. How long is the path traveled by each turtle?

The solution to this well-known problem—that the path equals an edge of the square—is reached most easily by working from the turtle's point of view. A turtle is a small creature that inhabits a computer's graphic-display screen. It has the ability to move forward or backward a specified distance and to turn in place clockwise or counterclockwise through a given angle. Distances and angles are arguments in turtle commands. Just as straightedge and compass are the basic tools of traditional geometry, so the turtle is the implement of turtle geometry.

Turtle Geometry, by Harold Abelson and Andrea A diSessa, discusses using the computer to explore mathematics. The authors make a persuasive case for their idea that compared with traditional methods, the computational approach encourages mathematical exploration at an earlier stage of learning.

The turtle leads the learner on quite a different mathematical journey than does traditional geometry. The earliest ideas presented in this book later are found to bear important relationships to topological concepts. We first learn of the distinction between *intrinsic* and *extrinsic* properties—intrinsic properties are those that do not require a frame of reference for their expression. A second important distinction concerns *local* versus *global* representations. Circles are constructed locally, meaning that the turtle does not know about the rest of the plane when making a small piece of a circle. Many of the turtle's constructions are both intrinsic and local.

Remember that the turtle can turn in place through any specified angle. If he keeps track of his turning by adding all clockwise turns and subtracting all counterclockwise turns, he immediately discovers the *Closed-Path theorem*:

> The total turning along any closed path is an integer multiple of 360 degrees.

The approach of turtle geometry is empirical. You obtain a result like the Closed-Path theorem, then try to improve it, exploring its consequences for various kinds of paths. Before long you have made a new discovery, perhaps in a different branch of mathematics. It is a tribute to the richness of turtle geometry that by the end of the first chapter you are studying the Euler ϕ function and Fermat's "Little" theorem, both number-theoretic ideas.

Because the turtle is an animal, it is only natural to explore turtle movement as behavior in response to controlling stimuli. Much can be learned by programming the turtle to model various types of forced movement, such as movement toward or away from stimulation. (For explanations of forced movement, see *Orientation in Animals* by G Fraenkel and D Gunn. Dover, 1961.) You can even set up experiments in which the turtle is responding to information from more than one sense simultaneously.

The turtle can be used for modeling patterns of growth found in nature. The principle of uniform growth leads to the shape of an equiangular (logarithmic) spiral. Many other fascinating designs, such as the spiral shapes found in seashells, arise from invoking simple turtle procedures recursively. (See *On Growth and Form*, by D Thompson. Cambridge University Press, 1961.)

The book provides a painless introduction to vector methods. The brief excursion into linear algebra is the book's only "corruption" (by Cartesian analytic geometry) of turtle geometry, and it is both appropriate and worthwhile. You learn here how to represent three-dimensional objects in two dimensions. Parallel projection is presented first, then perspective projection. Anyone who appreciates arcade games or is interested in their design will find this chapter enlightening. The geometric bases of changing perspective, zooming, and the like are explained.

Any computer with good graphics may be used to implement turtle geometry. (A commercial version is available for the Apple.) A well-structured language such as Pascal is desirable, but not essential, to implement the turtle routines.

Inevitably, the turtle escapes from the plane. Turtle spherical geometry is the first nonplanar generalization. A beautiful local definition of *geodesic* is developed:

> A turtle line is an equal-strided turtle walk.

Equal-strided means the turtle's left and right sides move equally. The beauty of this definition is that it applies to any surface. Remember, the total turning around a closed path is an integer multiple of 360°. As it turns out, the turtle can execute a closed path on nonplanar surfaces with a net 360° change in heading, but a total turning *not* equal to 360°. The discrepancy can be detected *intrinsically*. The concept, called *angle-excess*, gives rise to the important property called *curvature*. Further exploration brings us to the domain of topology, where we encounter theorems such as, "Any one-holed torus (doughnut-shaped surface) has zero total curvature."

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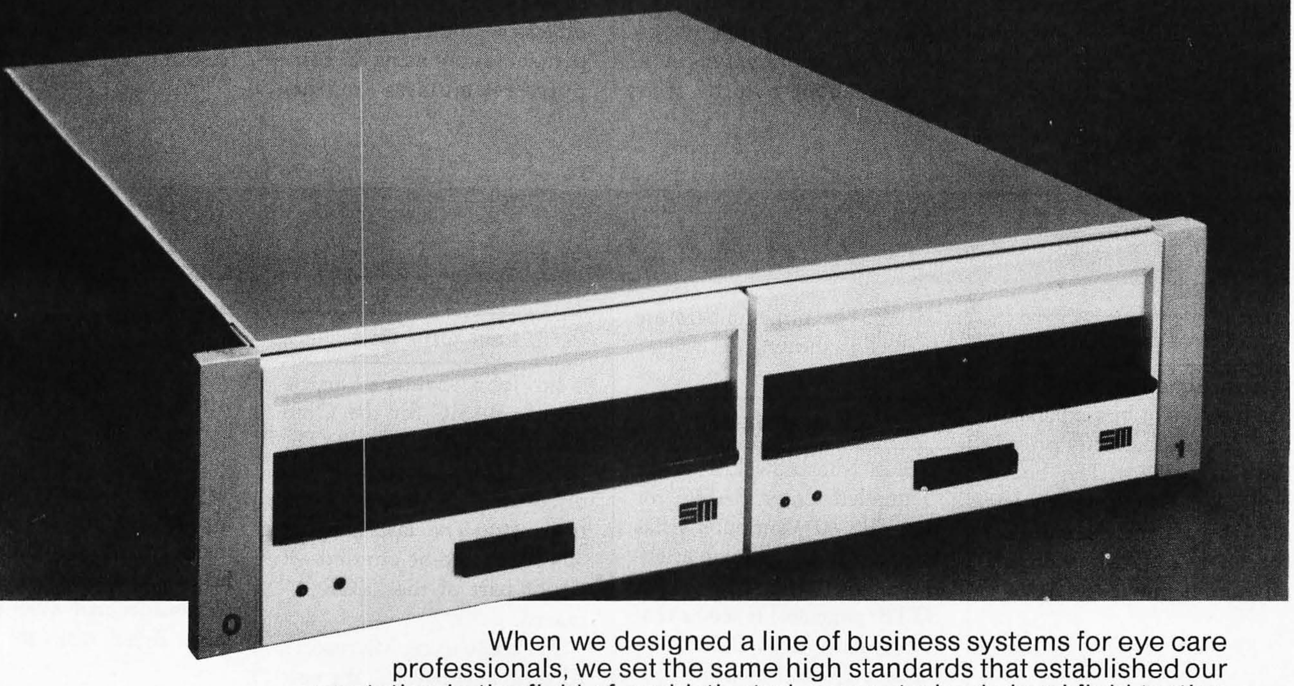

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Any surface in three dimensions can be deformed into a piecewise-flat surface. Piecewise-flat means, simply, that the surface is made of flat pieces joined at the edges. If the edges are straight, then all of the curvature is concentrated in the vertices. Piecewise-flat surfaces are easily represented in a computer program by an atlas which specifies all matching edge pairs by their face and edge numbers. Since a piecewise-flat deformation preserves all the topological properties of a surface, these properties can be studied as they are exhibited in this special case. For example, an important theorem, Gauss-Bonnet, states that the total curvature of any closed surface is:

$$2\pi(V-E+F)$$

where V is the number of vertices, E the number of edges, and F the number of faces.

The turtle's wanderings take him, finally, to the domain of curved space and general relativity theory. Gravity as a property of geometry is presented in a parable about a turtle who lives near the north pole of a sphere. He constructs a two-dimensional Euclidean model of his experience. Inevitably, the turtle encounters various strange problems with his model. He eventually overcomes his difficulties by postulating a force which acts everywhere locally. The force is called "demon-turning."

Traditionally, mathematics has shunned the computational approach. The main thesis of Abelson and diSessa's book is that experimentation using a computer stimulates mathematical discovery. The thesis is certainly true of turtle geometry, and one suspects it applies to many other areas of mathematics. Reading this book with the help of a good graphics computer system, you are sure to discover new and interesting math. *Turtle Geometry* is a serious effort to blend the computer with mathematics. It would serve as an excellent textbook or self-study guide. Perhaps it will also serve as a model for other efforts to bring the computer and mathematics to fruitful collaboration. ■

BYTE's Bugs

Corrected Price

In the June 1981 BYTE, Axlon Inc's 8-slot bus expansion board was incorrectly priced. (See page 420.) The board costs $895. The company has also released new pricing on the RAMCRAM memory module. It now costs $225.

Blasted Bugs

In the August 1981 BYTE "Software Received," the price for Budgeco's Raster Blaster was incorrectly listed. The correct price is $29.95.

We apologize for the mistake.

Super Simple Bug

An integrated circuit was incorrectly labeled in James Nicholson and Roger Camp's article "Build a Super Simple Floppy-Disk Interface, Part 1." (See the May 1981 BYTE, page 360.)

In Figure 4b on page 372, IC9 should be numbered 74193. The pin numbers are correct as shown.

Color PEEKs

Stan Miastkowski's article "Extended Color BASIC for the TRS-80 Computer" has been the focus of much attention. (See the May 1981 BYTE, page 36.) It seems that the system does indeed include a PEEK function, contrary to what was previously printed. The author replies:

I admit that I goofed. For BYTE to run an article on Extended Color BASIC at about the time it became widely available in Radio Shack stores, the company provided me with one of the first production models and a rough draft of the documentation. The rough manual had a list of differences, one of which showed that PEEK was not available in the nonextended model of the TRS-80 Color Computer. It was, however, available by the time the manual reached its final stages, but that was too late for inclusion in the article.

Last One Out

In John Sauter's article "Faster BASIC for the Ohio Scientific" (May 1981 BYTE, page 236), an error was discovered in listing 3 on page 240. The last line, an "INY", should be omitted—it is not part of the "ROR A" macro.

For those using Microsoft's KIM or TIM BASIC, the new code would be as shown in listing 1.

Another bug was found when using the 5-inch disk version. The code to be patched is on track 04, not 03 as published. Also, when using smaller disks, the top memory should be set at hexadecimal 4200 as opposed to hexadecimal 47FF for the larger 8-inch disks. ■

Listing 1

```
$37C2   B0 18   BCS   $37DC
$37D1   76 02   ROR   $02,X
$37D3   76 03   ROR   $03,X
$37D5   76 04   ROR   $04,X
$37D7   68      BLA
$37D8   6A      ROR   A
$37D9   C8      INY
$37DA   D0 E8   BNE   $37C4
$37DC   18      CLC
$37DD   60      RTS
    ($37DE through $3801 now unused)

$38C3   66 73   ROR   $73
$38C5   66 74   ROR   $74
$38C7   66 75   ROR   $75
$38C9   66 76   ROR   $76
$38CB   66 BD   ROR   $BD
$38CD   98      TYA
$38CE   4A      LSR
$38DF   D0 D6   BNE   $38A7
$38D1   60      RTS
    ($38D2 through $3903 now unused)
```

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Photo 1: *Advanced TIROS-Class Weather Satellite. Used in military and civilian versions, the TIROS satellites have two on-board computers.*

One Step Forward—Three Steps Backup

Computing in the US Space Program

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A special tension surrounds the development of a computer system for use as the main computer aboard a spacecraft. On one hand, such a computer must be able to perform complex operations. On the other, since the first extraterrestrial service call by a field engineer is yet to be made, an on-board computer system must do its work with absolute reliability despite the most demanding environmental conditions. And by the time a computer's reliability has been proved beyond a doubt, more efficient computers have appeared on the market. It's almost as if the same process that proves a computer's reliability also ensures that the computer will be obsolete before it flies. Developing a main on-board computer is both a battle to prevent a catastrophic failure and a race against obsolescence.

The advent of the space shuttle (known more formally as the Space Transportation System) will soon enhance the requirement for reliability on orbital missions. Moreover, the shirt-sleeve environment of Spacelab will prove an opportunity to use off-the-shelf microprocessor systems to support scientific experiments. But *space-rating*—establishing the fitness of hardware for use aboard a spacecraft—will remain a severe test, especially for computers that control life-critical and mission-critical systems.

In this article, I'll first discuss the requirements of space-rating. Then I'll describe the tasks that a main on-board computer must perform and some of the capabilities needed to perform those tasks. I'll go on to discuss the problems of providing

ground support for on-board software.

After a glance at the historical development of on-board computers, I'll look at some devices now in use. Finally, I'll describe applications of microprocessors in noncritical functions aboard spacecraft. (Yes, there will soon be an Apple in orbit.) Throughout the article, I will confine my comments to civilian spacecraft of the United States.

Space-Rating

Equipment and software that must operate for long periods unattended in the difficult environment of space must be very reliable. Space-rating is the process that demonstrates the reliability of equipment for use on spacecraft. The process requires careful testing of parts, components, assemblies, modules, and software. Space-rating standards are stricter than specifications for military equipment.

Here are a few of the things that a main on-board computer in the mid-1980s must be able to do:

- withstand repeated heating and cooling from +50° Celsius to −10° Celsius

- function despite exposure to mechanical shocks, electromagnetic disturbances, high-energy particles, and radiation

- withstand forces from 0 to 30 gravities

- perform calculations on the level of evaluating 1300 long time-series polynomials per second to 32 bits of precision

- undergo intensive use for periods of several years without experiencing a single failure

Although space-rating standards of reliability are always stringent, they depend to some extent on the kind of mission for which the spacecraft is intended.

Mission Classes

Missions usually fall into one of three classes: *manned missions, planetary-probe missions,* and *unmanned earth-orbiting missions.*

Manned missions require the highest standards of reliability. When an astronaut's life is at stake, there is no room for failure. This principle is reflected in the record of the Apollo program: as a result of *2000 man-years* of development and testing, there were *no* flight-critical errors of spacecraft software (see reference 8).

The most common way to establish reliability in spacecraft equipment is to build in redundancy. The Shuttle Orbiter vehicle, for example, has five general-purpose computer systems to control all aspects of its operation. In certain critical operations, four of the five systems will perform the same task, providing three levels of backup.

More recently, concern for the lives of astronauts has led to the adoption of a rule that the Shuttle Orbiter will not be allowed to approach "dead" spacecraft. Unless telemetry indicates that an unmanned satellite still has effective attitude-control and a certain level of stability, the Orbiter crew (and the extremely expensive Orbiter itself) will not be committed to approach the satellite. In addition, any satellite intended for launch as a shuttle payload must pass the same stringent requirements as a manned spacecraft.

Although no lives are at stake in their use, planetary-probe spacecraft also impose stringent requirements on on-board computer sysems. The long flight times to distant targets, the hostile environments traversed, and the impossibility of retrieval or repair all increase the demands placed on equipment. Planetary-probe spacecraft are very much on their own.

Photo 2: *Shuttle Orbiter mounted on transport aircraft. The Orbiter has five on-board computer systems, configured to provide as many as three levels of backup in critical situations. Two chase planes are visible.*

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The distance between spacecraft and earth is often so great that radio signals require long periods to travel between the two. When the target is one of the outer planets, communication may take more than a half hour each way. By the time the ground station receives a message indicating a problem aboard the spacecraft, too little time may remain to send messages intended to correct the problem. The design requirements for computer systems aboard planetary-probe spacecraft are perhaps an order of magnitude beyond those for systems aboard spacecraft operating near earth.

Most spacecraft carry out unmanned earth-orbiting missions. These missions may have either near-earth orbits or synchronous-altitude orbits. Spacecraft can remain synchronous with the rotation of the earth only by orbiting at extremely high altitudes. Since the Shuttle Orbiter can't deploy or retrieve spacecraft so far from earth, synchronous-altitude spacecraft must be built to function without service for the duration of their missions.

A spacecraft at synchronous altitude appears to remain stationary above one point on the earth's equator. Consequently, a ground station can stay in continuous communication with such a spacecraft. In this respect, spacecraft at synchronous altitude are easier to manage from the ground.

Satellites orbiting the earth at lower altitudes appear to "rise" and "set" over the ground station. A typical orbit takes about 90 minutes, and the spacecraft is in view of a given tracking station for only 10 minutes of the 90. The ground station must pack a great deal of communication into the 10 minutes of contact. During those 10 minutes, the ground station has to send up enough commands for the next 80 minutes of operations, check the state of all on-board systems, take any necessary corrective action, and dump recorded data from the satellite to the ground over a high-speed channel.

During the 80 minutes when the satellite is out of touch with the ground, the on-board computer must sequence and monitor spacecraft operations and components and store messages about the status of monitored equipment. In case of problems, the on-board computer must take first-order corrective action. Even with the advent in the early 1980s of NASA's tracking station in the sky—the synchronous-altitude Tracking and Data Relay Satellite System (TDRSS)—full coverage of satellites in near-earth orbits will not be assured because so many satellites will share use of TDRSS.

Space-Rating Microprocessors

Microprocessors, memories, and interface devices aboard spacecraft must operate in a vacuum over a wide temperature range. The vacuum restricts cooling to radiation and conduction; since no atmosphere is present, convection is impossible. Besides the limitations on cooling, equipment

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must be able to withstand a wide temperature variation while dormant. The dormant period includes launch and recovery, during which there is no assurance that the spacecraft can maintain adequate thermal control.

Periodic and random vibration and mechanical shock may also damage electronic equipment during the launch phase. A common failure is breakage of a bonded lead wire where it is attached to the die of an integrated circuit. High inertial gravity (g) loads can cause such breakage. Space components are usually tested in steady-state acceleration in excess of 30 gs. Instantaneous accelerations, such as those undergone by a chip that is dropped onto a solid floor from a height of approximately a meter, can exceed hundreds of gs.

Components of space-borne systems must neither generate electromagnetic disturbances nor be vulnerable to them. The proximity of other electronic devices and of moderate-power transmitters of radio-frequency energy requires resistance to electromagnetic disturbances.

The abundance of radiation and high-energy particles pose another threat to semiconductor devices in space. Although there is a self-healing effect if semiconductors are turned off for a while, periodic failures are unacceptable in mission-critical functions.

Table 1 shows the radiation "hardness" of several microprocessors. In general, radiation damage is cumulative. Microprocessors of commercial grade fail at several thousand rads total dosage. Although it is possible to attempt shielding chips with aluminum paneling, results are not encouraging. Often, when one high-energy particle strikes the aluminum, more than one high-energy particle comes out the other side.

P-type metal-oxide semiconductors (PMOS) are generally less susceptible to radiation damage than are the newer and faster N-type metal-oxide semiconductor (NMOS) devices. Radiation-hardened versions of standard device-families are available, particularly complementary metal-oxide semiconductor (CMOS) devices, which are faster than PMOS but slower than NMOS. This is but one instance of space-borne technology lagging behind current commercial technology.

Perhaps the most serious hurdle that microprocessors must face before becoming main on-board computers is one of sheer computational power. Many of the calculations required of these machines need a word length greater than 16 bits. Until the appearance of 32-bit microprocessors, less highly integrated devices will retain their monopoly as main on-board computers.

Device	Type	Technology	Suitable Support Circuits	Projected Hardness, in Rads	Power of Basic Processor, in Milliwatts (mW)
RCA 1802*	Monolithic	CMOS	Memories, Some I/O	10^5	30
TI-SBP9900	Monolithic	I^2L	Memories Only	10^7	500
Intersil 6100	Monolithic	CMOS	Memories, Some I/O	10^5	50
Intel 8080A	Monolithic	NMOS	Memory, Some I/O	10^3	1700
AMD 2900*	Bit Slice	LS-TTL	Memory, All I/O	10^7	10,000 (16 bit)
Intel 3000*	Bit Slice	S-TTL	Memory, All I/O	10^7	15,000 (16 bit)
NMI 6700	Bit Slice	LS-TTL	Memory, Some I/O	10^7	15,000 (16 bit)

* Multiple sources available.

Table 1: *Comparison of microprocessors for space applications. Included are each processor's radiation "hardness" and its average power consumption.*

On-board Computer Tasks

Designers of spacecraft have been relying more and more on on-board computers and associated data systems to give the spacecraft flexibility and autonomy. Tasks assigned to the on-board computer include:

- *Attitude determination.* Orienting the spacecraft in space is a vital and complex function. The spacecraft data system must give the computer data from sun- and star-trackers, earth sensors, and gyros. The attitude-determination algorithm calculates how the spacecraft should be aligned with respect to inertial axes. The attitude-control algorithm then issues commands that enable magnetic thrusters, jet torquers, or reaction wheels to point the spacecraft (ie: align the axes) to a desired point on earth or to a star. Attitude determination and control, sometimes including orbit-adjust software, typically require 4 to 12 K bytes of memory.

- *Command Storage.* The on-board computer can store sequences of commands that are "time-tagged" for later execution. Storage may also include predefined blocks of frequently executed command sequences (macros).

- *Executive.* A real-time, multitasking, interrupt-driven executive is used to sequence all tasks and to handle input/output operations.

- *Housekeeping.* This includes monitoring and controlling thermal and electrical power. These tasks may require continual monitoring and limit-checking of sensors in the spacecraft. Spacecraft housekeeping may also include continuous measurement of the batteries' charge.

- *Telemetry Format Control.* The on-board computer may control the sampling and format of the on-board telemetry points. This makes reconfiguration possible in response to degradation and failures. If a prede-

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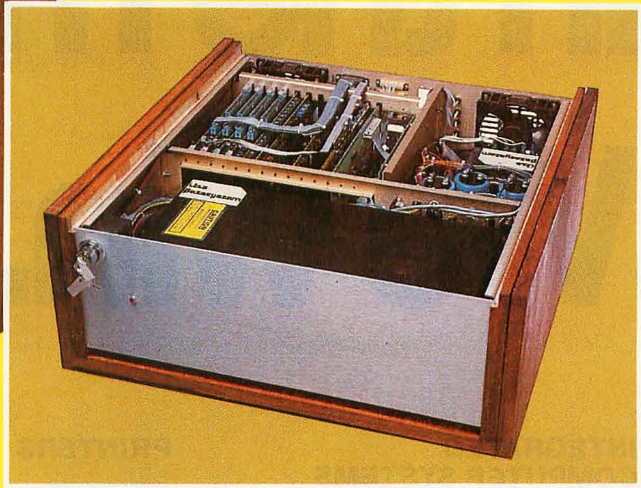

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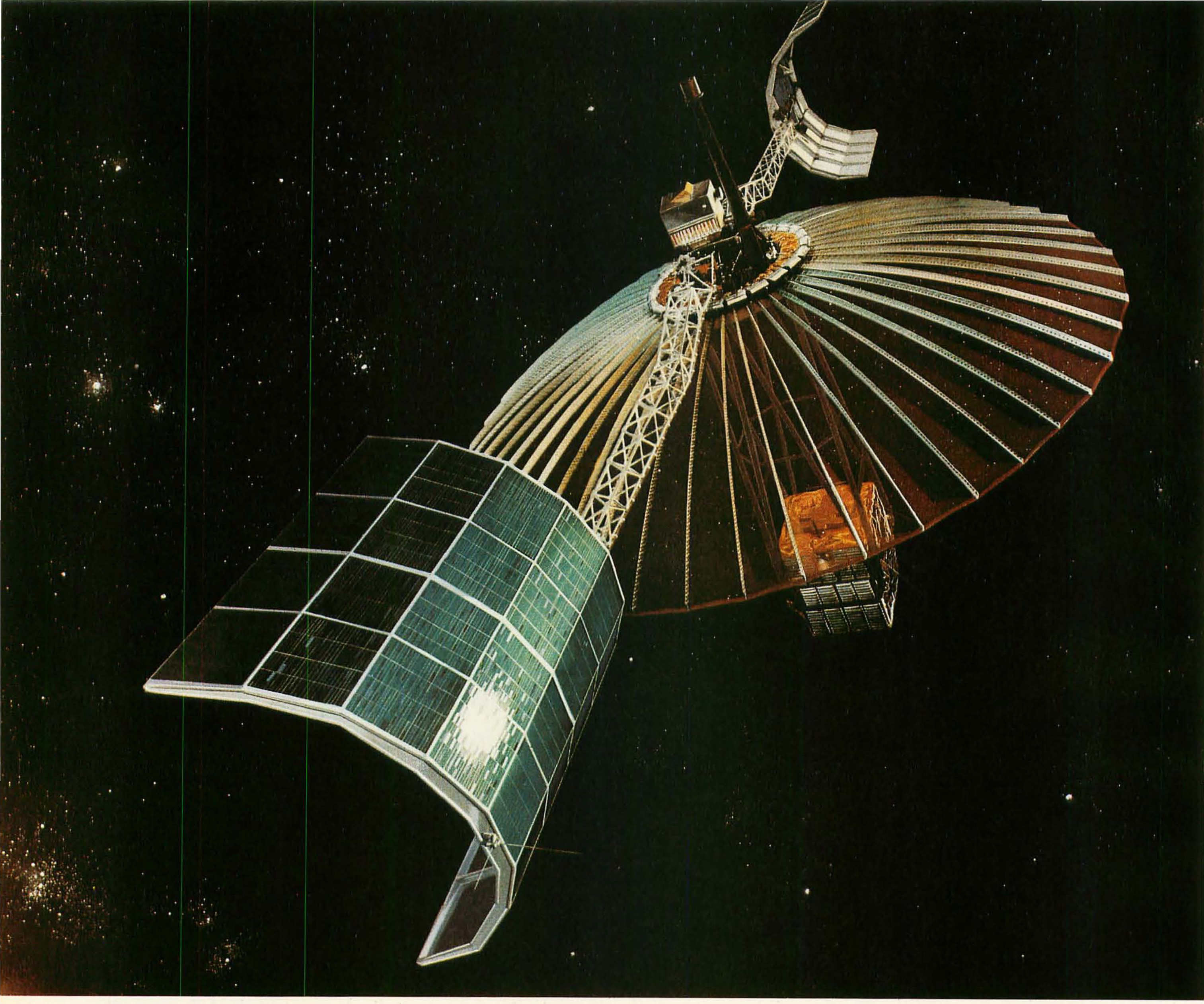

Photo 3: *ATS-6 Communications Satellite. Traveling in synchronous orbit, the ATS-6 uses two on-board computers for attitude control.*

fined telemetry format is changed in order to circumvent a hardware problem, the input on the ground-based telemetry processor must, of course, be changed, too.

• *Instrument Sequencing and Control.* The on-board computer can monitor and control instruments directly or can support the instruments' dedicated microprocessors. In addition, the on-board computer can manage storage of data. Data is recorded during the "back orbit," when the spacecraft is out of touch with the ground station. When the spacecraft reestablishes contact, data is dumped to the ground over a high-speed data link.

Some Essential Capabilities

On-board computers must constantly perform complex mathematical computations such as coordinate transforms. Floating-point capability enables on-board computers to perform these computations efficiently.

The alternative to building in floating-point capability has been to use scaled fixed-point operations. In testing, operation, and maintenance, however, the scaled fixed-point approach has led to problems with overflows, notably aboard Applications-Technology Satellite-6, the International Ultra-violet Explorer, and the Solar Maximum Mission. These experiences have led to the choice of integral floating-point capability in the on-board computers' processors.

Designers may implement floating-point capability in several ways. The most attractive is to have floating-point capability as part of the machine architecture. The architecture of several on-board computer systems in the 1980s will implement floating-point capability. If a processor can't perform floating-point operations, the designer can add the capability by introducing a slave processor. The slave processor may rely on calculator or computer technology, or it may be a co-processor, sharing the main processor's address, data, and control space.

Designers sometimes add firmware containing math-library functions

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such as SIN/COS, ATAN, and SQRT, based on the primitive floating-point operations. Ideally, the on-board processor would have both floating-point operations and math-library functions as standard features. The co-processor and firmware approaches are interim measures to be considered only so long as technological restrictions prevent including these features in the main processor.

Processor	Approach Used (see table 3)	Format	Time Needed for Operation in Microseconds (μs) Add/Subtract	Multiply	Divide
NSSC-1/SP-C32	1b	24/8[1]	16.5	11.5	27.0
LSI-11	2	24/8[2]	42.1 to 66.2	74 to 121	151 to 232
ATAC-16MS	2	24/8	5.75	16	28.5
AM9511[3]	1b	24/8	13.5 to 92	36.5 to 42	38.5 to 46
57109[3]	1a	8-decimal-digit-mantissa, 2-digit-decimal exponent	22,000 to 66,000	32,000 to 227,000	78,000 to 223,000
8087[4]	1c	32 bits; 10 decimal digits	18	18	27

[1] 24-bit mantissa/8-bit exponent
[2] Essentially 25-bit mantissa
[3] Slave processor only
[4] Co-processor with 8086/8088

Table 2: *Comparison of arithmetic operations in floating-point hardware.*

Floating-point capability (in the 24-bit-mantissa/8-bit-exponent format) requires at least a 16-bit and preferably a 32-bit word size. Several on-board computer systems in the 1980s will have floating-point capability, and at least one of these will have integral math-library functions.

Table 2 compares the floating-point capabilities of several kinds of hardware used in on-board computers. Table 3 shows the advantages and disadvantages of different ways of implementing floating-point capability. Table 4 shows execution times of math-library functions in different processors.

Higher-Order Language

The complexity of the mathematics to be performed aboard a spacecraft gives considerable appeal to the use of a higher-order language in developing flight code. The computer, of course, is indifferent to the programming language or method used. The question is whether higher-order lan-

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Number (see table 2)	Type of Approach	Advantages	Disadvantages
1a	Add-on arithmetic processor	Built-in math functions	Slow
1b	Add-on microprocessor	Fast—may proceed in parallel with main microprocessor	Interfacing; no-math library
1c	Co-processor	Faster; math-library available	Architecture and interfacing problems
2	Functions built into main microprocessor	Very fast	Usually no math-library; math functions must be written in software

Table 3: *Comparison of different approaches to floating-point capability.*

(a)

Processor Used	Accuracy (in bits)	Implementation Time for Fixed-Point Calculations in Microseconds (μs) SIN/COS	ATAN/ASIN	SQRT
9900, with software	16	109	236	117
NSSC-1, with software	18	163	417	190
LSI-11, with software	16	176	544	184

(b)

Processor Used	Implementation Time for Floating-Point Calculations in Microseconds (μs) SIN/COS	ATAN/ASIN	SQRT
LSI-11 with floating-point hardware	784	1303	767
NSSC-1/SP-C32	265.2	311	223
ATAC-16MS	121.2	235	123.6

(c)

Processor Used	Format Used	Implementation Time for Calculation by Inherent Math-Library Functions in Microseconds (μs) SIN/COS	ATAN/ASIN	SQRT
AM9511*	Floating-Point	1084.25	1384	206.5
59109*	Decimal	760,500	620,500	186,000
8087	Co-processor	N/A	N/A	36

* Average of minimum and worst case times

Table 4: *Implementation times of several math functions in different processors. The functions considered are sine, cosine, arctangent, arcsine, and square root. Table 4a shows the times for fixed-point implementations. Table 4b shows the times for floating-point implementations. Table 4c shows miscellaneous processor/format combinations.*

guages increase programmers' efficiency. Many programmers now think that they can work more efficiently in higher-order languages than in assembly language.

But will the use of higher-order languages make testing and maintaining software more difficult? It remains unclear, during operation of a spacecraft, whether code produced in assembly language is easier to debug and change than code produced by a higher-order-language compiler. But the experience of producing the flight code for the Space Shuttle suggests that language derived from a higher-order language is no more difficult to debug and may even be easier.

Among the higher-order languages that are candidates for use with onboard computers are Jovial, HAL/S, and Ada/Pascal. Each has advantages and disadvantages. (Space Programming Language [SPL] was developed by RCA for in-house use and never gained wide acceptance.) In the absence of an effort to develop a compiler, however, designers will have to use whatever language is supplied by the manufacturer of the hardware.

Pascal-like languages impose structured techniques on programmers. Some programmers have faulted Pascal because each program in that language is an entity, lacking external references. But, in creating software for flight-loads, this feature of Pascal should be an advantage because flight-load software must function as an entity. Moreover, Pascal has gained wide acceptance among programmers. And the Department of Defense has adopted Ada, a Pascal-

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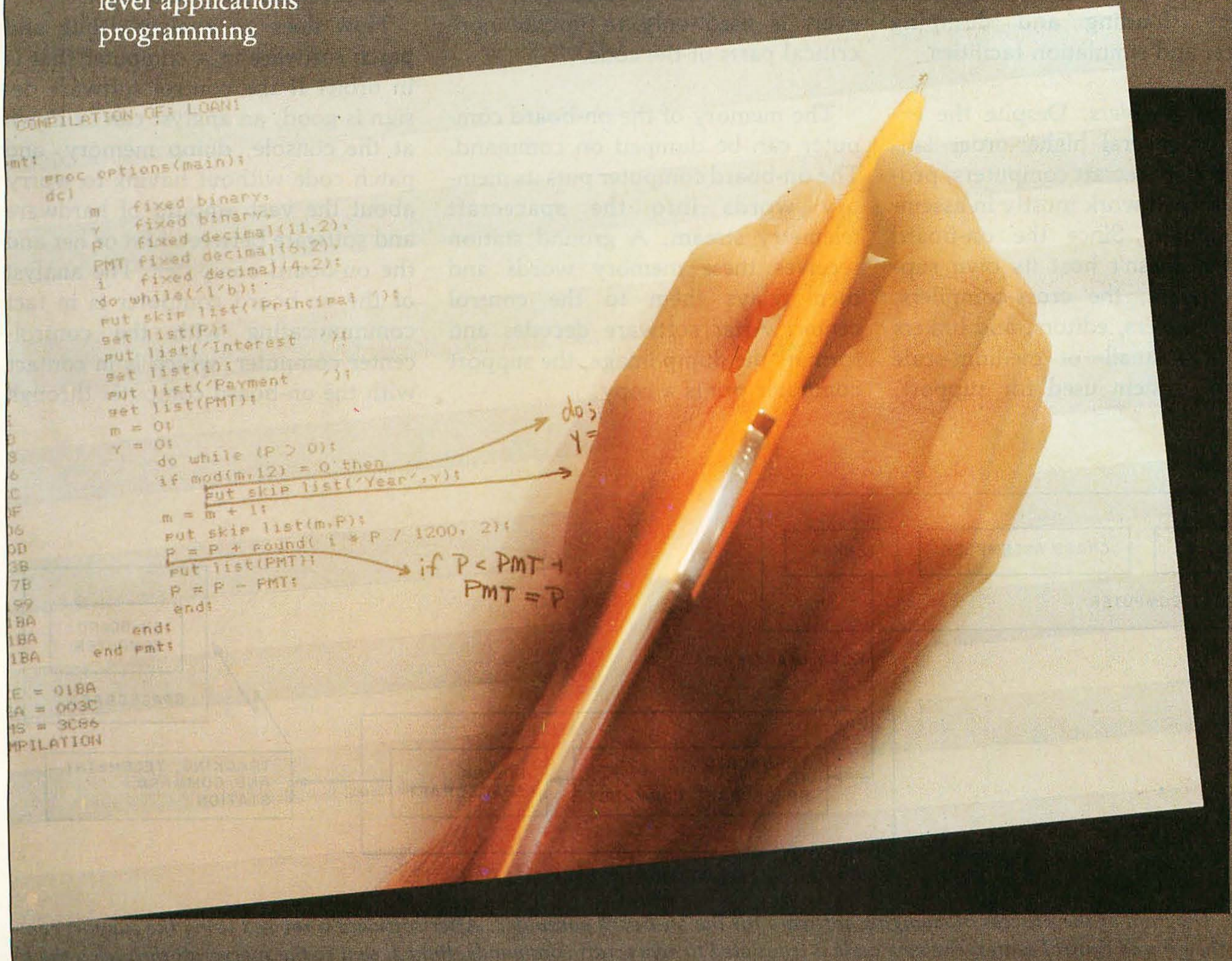

like language.

HAL/S was created specifically for generating flight software, but is not designed for use with a small processor. As with all higher-order languages, HAL/S will only be as good as its compiler implementation, which translates programs into machine language.

The choice of which higher-order language is used may not be critical. It would probably not be cost-effective to develop a compiler specifically for use in the space program because all the recommended on-board machines for the 1980s include one higher-order-language compiler. Note, however, that all these compilers must be cross-compilers because the flight processor can't support a compiler of its own.

Supporting Software

The tools that programmers use to develop and maintain software for on-board computers include cross-assemblers, loading and dumping facilities, and simulation facilities.

• *Cross-Assemblers.* Despite the existence of several higher-order languages for spacecraft computers, programmers still work mostly in assembly language. Since the on-board computer doesn't host its own support software, the cross-compilers, cross-assemblers, editors, and linkers reside in a small- or medium-scale computer system used for support. Programmers work on this support system, using its convenient facilities such as video display, disk and tape drives, and a printer. The code produced is then "downline loaded" to the flight computer or test facility or transferred via tape image.

• *Loading and Dumping.* The software load-image for the on-board computer must be mapped into spacecraft commands through the command link, as shown in figure 1. The ground control center usually does this mapping, and then uplinks the commands to the spacecraft via a tracking, telemetry, and command station. On the spacecraft, the command receiver routes the commands to the computer, where they are interpreted. The NSSC-1 on-board computer, discussed at length later, can be hardware-loaded (without the intervention of on-board software) or can be loaded by use of the executive program. The latter technique, however, is used only to update noncritical parts of the code.

The memory of the on-board computer can be dumped on command. The on-board computer puts its memory words into the spacecraft telemetry stream. A ground station receives these memory words and then relays them to the control center. After software decodes and formats the dump image, the support computer prints a copy.

Simulation Facilities

NASA often uses simulation to test the hardware and software of on-board computers. A program hosted in a mini-computer or in a still larger machine is made to appear to the on-board computer as the rest of the spacecraft. A large and complex real-time simulation generates sensor data and accepts torquer commands, exercising the on-board computer in many different hypothetical situations. In addition to serving as the major debugging and analysis tools for flight software, simulations are used to train control-center crews.

Debugging Software in Orbit

After thousands of man-years of testing, an on-board computer is launched and assumes full control of spacecraft operations. All too often, the on-board computer crashes because of an obscure and improbable set of conditions that no one even dreamed of simulating.

How does an analyst debug and patch software in a computer that is in orbit? If the control software design is good, an analyst can sit down at the console, dump memory, and patch code without having to worry about the vast amount of hardware and software between him or her and the on-board computer. The analyst of the on-board computer is in fact communicating with the control-center computer, which is in contact with the on-board computer through

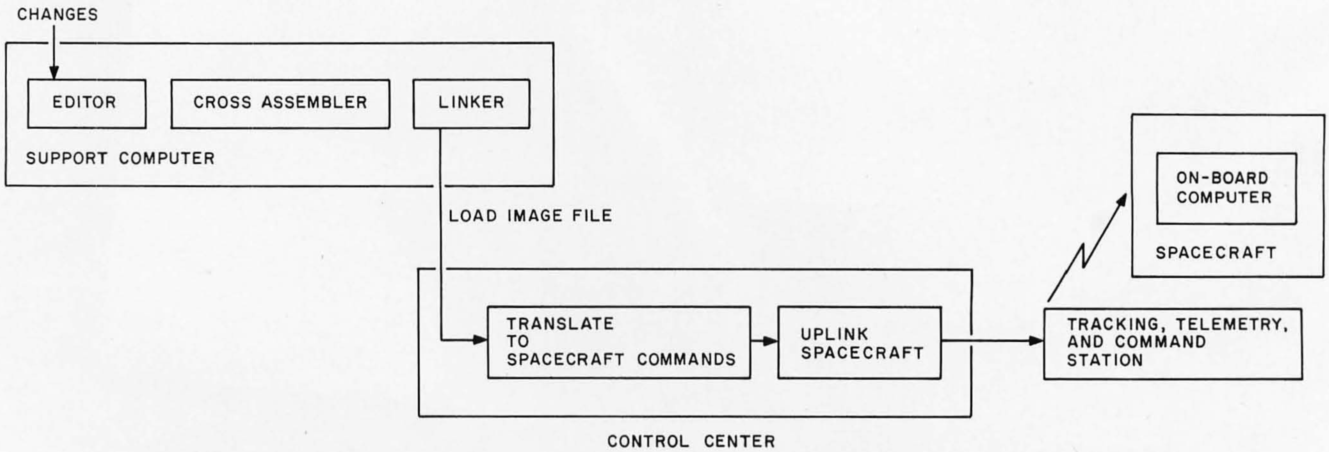

Figure 1: *Diagram of the process of changing software for the on-board computer. After software is revised using the support computer in the ground control center, the new code is translated to spacecraft commands, linked, sent to the spacecraft through a tracking, telemetry, and command station, and placed into the spacecraft's on-board computer.*

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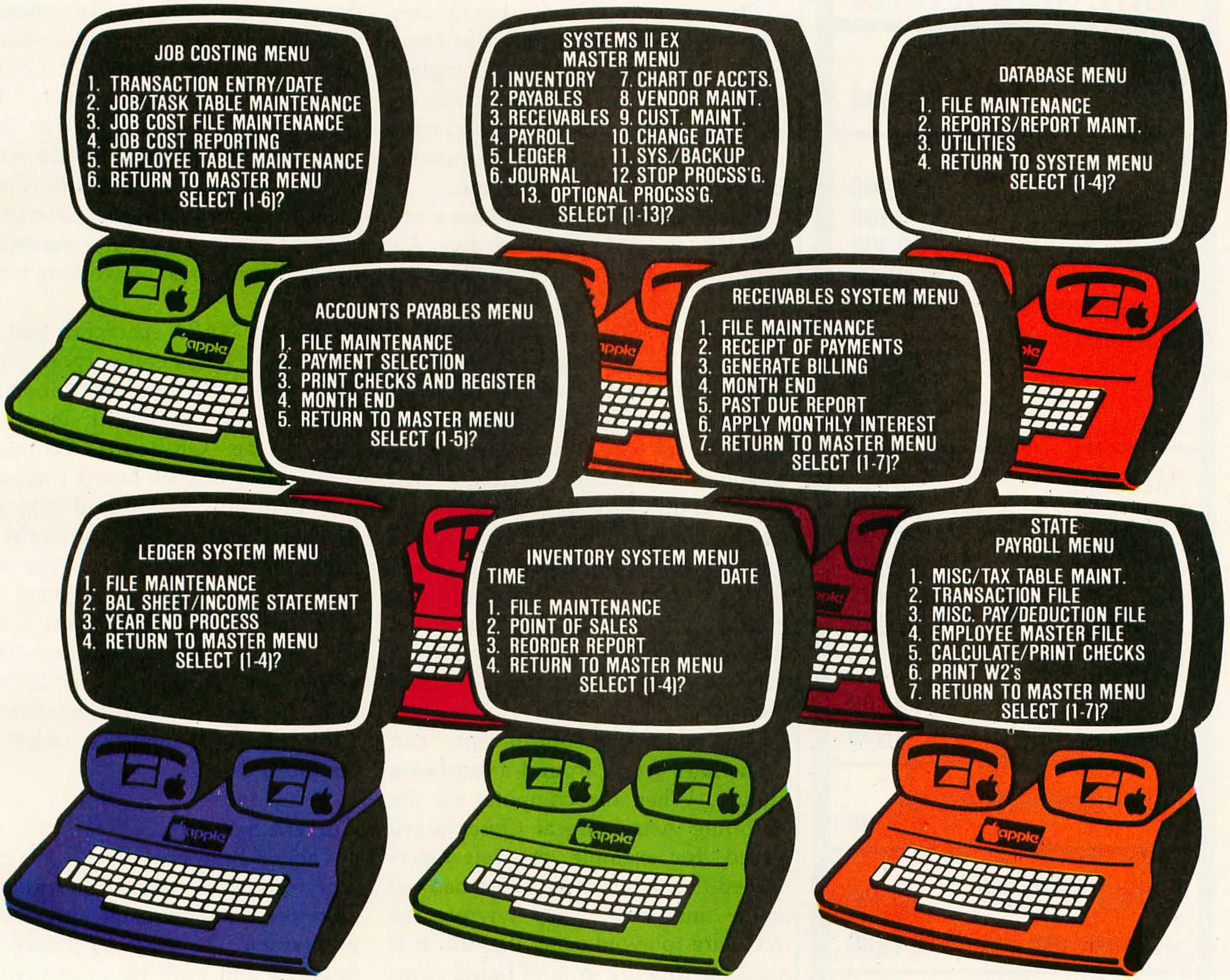

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Fixing Failures in Orbit

Once diagnosed, software failures can be corrected by partially or completely reloading memory. Complete reloads are possible but time-consuming. Remember that the ground control center often has only 10 minutes in every 90 for communication.

Hardware failures in orbit are more difficult to diagnose and fix. Although the Shuttle Orbiter will have a tape drive for storing software, most on-board computers lack mass-memory units. Using disk drives in orbit, except in the largest vehicles, leads to problems because of the need to compensate for the drives' rotational angular momentum. Perhaps two identical disk drives revolving in opposite directions would compensate for each other. But the main problem in fixing hardware is that only one technique is possible: turning off the equipment for a while. This treatment fixes some failures caused by radiation.

Analysts in the control center can sometimes work around a hardware failure. When the computer on the Orbiting Astronomical Observatory failed, for example, analysts determined that a bit in the adder had become unreliable. They rewrote the software to avoid using that bit. It is possible to work around failed memory in a similar fashion.

In the era of the space shuttle, it will be possible to replace modules containing a failed computer or even to bring an entire spacecraft back to earth for repairs. Most current spacecraft designs incorporate hard-wired functions, independent of on-board computers, that will enable the Space Shuttle to approach and retrieve a spacecraft that has a malfunctioning computer.

Early Systems

Spacecraft computers started out as a natural outgrowth of missile-guidance computers—simple sequencers. In the late 1950s and early 1960s, missile-guidance computers were ground-based and had tube or transistor technology. One of these early devices is on display at the Smithsonian Museum of History and Technology in Washington, DC.

With the advance of technology, designers were able to place missile-guidance functions in an on-board computer. The main work of the missile-guidance computer remained the sequencing of operations. The missile-guidance computer had to work for only about 30 minutes. Computers aboard spacecraft, of course, have to perform a greater variety of functions and to go on working much longer.

The first NASA spacecraft that incorporated a general-purpose computer was the Orbiting Astronomical Observatory, launched in 1972. Called the On-board Processor (OBP), this first on-board computer was built by NASA and was the precursor and engineering model of the NSSC-1. Although the OBP was included mainly as an experiment, the computer helped prolong the life of the mission until December 1980 despite many on-board equipment degradations, including the failure of a bit in the computer's adder, as described earlier.

Current Systems

Table 5 shows details of some current on-board computer systems. Note that most missions include two processors. The AMSAT Phase III, designed and built by amateurs, includes a CMOS processor. Favored storage devices in current systems include core and plated-wire devices. The systems shown in table 5 contain no secondary memory storage. Preferred technology is high-reliability TTL (transistor-transistor logic) or radiation-hardened CMOS. Typical machine cycle times are several microseconds.

On-board computers are examples of embedded computer systems—they perform as subsystems and perform only a specific application. As microprocessor technology evolves toward a chip with a processor in the class of the IBM System 370, microprocessors will increasingly serve as on-board computers.

	Computer	Mission	Number	Memory Size	Memory Type	Type of Processor	Cycle Time
1.	NSSC-1	MMS(Generic)	1 or 2	8-64 K by 18 bits	CORE	TTL	1.5μs
2.	AOP	Landsat-B/C	1	4 K by 18 bits	PWM	TTL	—
3.	NSSC-1	SMM	2	48 K by 18 bits	PWM	TTL	1.4μs
4.	AOP	IUE	2	12 K by 18 bits	PWM	TTL	1.3μs
5.	OBP	OAO-C	1	16 K by 18 bits	CORE	DTL	2.0μs
6.	DOC	ATS-6	2	4 K by 16 bits	PWM	LPTTL	5.0μs
7.	GCSC	Viking Lander	2	18 K by 18 bits	PWM	LPTTL	5.0μs
8.	CCS	Viking Orbiter	2	8 K by 18 bits	PWM	—	—
9.	FDS	MJS-77 (Voyager)	2	8 K by 16 bits	CMOS	DMOS	2.48μs
10.	CCS	MJS-77 (Voyager)	2	8 K by 18 bits	PWM	—	1.37μs
11.	AACS	MJS-77 (Voyager)	2	8 K by 18 bits	PWM	—	1.37μs
12.	SCP-234	TIROS-N	2	18 K by 16 bits	CMOS	CMOS	2.34μs
13.	SCP-234(USAF)	Block 5D	2	16 K by 16 bits	CMOS	CMOS	—
14.	COSMAC	AMSAT Phase IIIB	1	16 K by 8 bits	CMOS	CMOS	1μs
15.	NSSC-1*	Landsat-D	2	64 K by 18 bits	CORE	TTL	1.5μs
16.	ATAC-16ms*	Galileo (AACS)	2	32 K by 16 bits	CMOS (hardened)	LSI bit slice	250ns
17.	CDC 469	HEAO	2	16 K by 16 bits	Plated Wire	PMOS/LSI	

Table 5: *Characteristics of some current on-board computer systems.* * Not yet launched.

Table 6 shows processors that are available for space missions in the 1980s. Among the features summarized in table 6 are the higher-order languages that are offered for use with these processors. The table also gives the times required by each processor for addition, multiplication, and division in both fixed- and floating-point operations.

Spacecraft Computer-1

Current plans call for use of the NASA Standard Spacecraft Computer-1 (NSSC-1) for flights using the Multimission Modular Spacecraft.

Computer Category	NSSC-1	NSSC-1 SP-C32	NSSC-11	ATAC-16ms	M3625	SCP-234
Manufacturer	IBM	IBM/MM	IBM	ITEK	Delco	RCA
Heritage to Previous Computers	SMM,IUE	None	None	ECW Avionics	TITAN III-C F-16	None
Space Applications	MMS	None	None	Galileo	IUS	TIROS-N
Fixed-Point Word Size, Bits*	18/35	18/35	32	16/32	16/32	16/32
Floating-Point Word Size, Bits*	35/18	24/8	24/8	24/8	24/8	N/A
Size, Cubic Inches	570	N/A	1232	609	1250	655
Weight, Pounds	17	N/A	28	18	54	7.9
Power, Watts	45	N/A	150	31	190	10
High-Order Language						
JOVIAL				•	•	
SPL				•		•
HAL/S	•					
Ada/Pascal				•		
Fixed-Point Execution Time, μs						
Addition/Subtraction	5	5	N/A	0.25	0.8	4.68
Multiplication	38	38	8.5	5.0	2.8	59
Division	75	75	17.5	10.2	5.8	101
Floating-Point Execution Time, μs						
Addition/Subtraction	393	16.5	N/A	5.8	2.6	N/A
Multiplication	580	11.5	38	17.5	4.6	N/A
Division	909	27	56	29.2	9.8	N/A
Cost in thousands of dollars	205	355	N/A	115	1600	N/A

* Bits in Mantissa/Bits in Exponent N/A = Not Available

Table 6: *Characteristics of processors available for space missions in the 1980s.*

CMOS	-	Complementary Metal-Oxide Semiconductor	
DTL	-	Diode-Transistor Logic	
LPTTL	-	Low-Power Transistor-Transistor Logic	
PWM	-	Plated-Wire Memory	
TTL	-	Transistor-Transistor Logic	
AACS	-	Attitude and Articulation Control Subsystem	
AOP	-	Advanced On-board Processor = NSSC-1	
CCS	-	Computer Command Subsystem	
μs	-	10^{-6} seconds	
ns	-	10^{-9} seconds	
DOC	-	Digital Operations Controller	
FDS	-	Flight Data Subsystem	
OBP	-	On-board Processor	
NSSC-1	-	NASA Standard Spacecraft Computer	
MMS	-	Multimission Modular Spacecraft	
SMM	-	Solar Maximum Mission	
IUE	-	International Ultraviolet Explorer	
OAO	-	Orbiting Astronomical Observatory	
ATS-6	-	Applications Technology Satellite	

Flying in various configurations, this modular satellite will perform many NASA missions.

The NSSC-1 occupies 122 cubic inches, weighs 3 pounds and requires a 5-watt power supply. A fixed-point, two's-complement computer with a word length of 18 bits, the NSSC-1 has 55 instructions and performs an add operation in 5 μs, a hardware multiply operation in 38 μs, and a divide operation in 75 μs. All these items are based on use of a 1.6 MHz clock. The NSSC-1 has one index register, one double-length accumulator,

MECA	DF-224	FTSC	469	GPC	CMOS/SOS	4516E
Teledyne	Autonetics	Raytheon	CDC	IBM	TRACOR	Litton
DELTA, CENTAUR	None	None	HEAO	N/A	AN/UYK-20	N/A
None	Space Telescope	None	None	Shuttle	None	None
16/24/32	24	32	16/32	36	1632	16/32
24/8	NO	N/A	NO	YES	24/8	YES
1091	N/A	N/A	N/A	N/A	N/A	N/A
49	102	50	10	59	N/A	18
74	85	35	20	350	5	34
•						
				•		
1.6	1.6	5.4	4	1.9	0.75	2.5
3.94	8	11	10.4	5.7	4	21
N/A	N/A	N/A	N/A	N/A	8	N/A
6.6	N/A	N/A	N/A	N/A	3.75	N/A
11.12	N/A	N/A	N/A	N/A	10	N/A
N/A	N/A	N/A	N/A	N/A	15	N/A
N/A	2250	1000	650	500	N/A	115

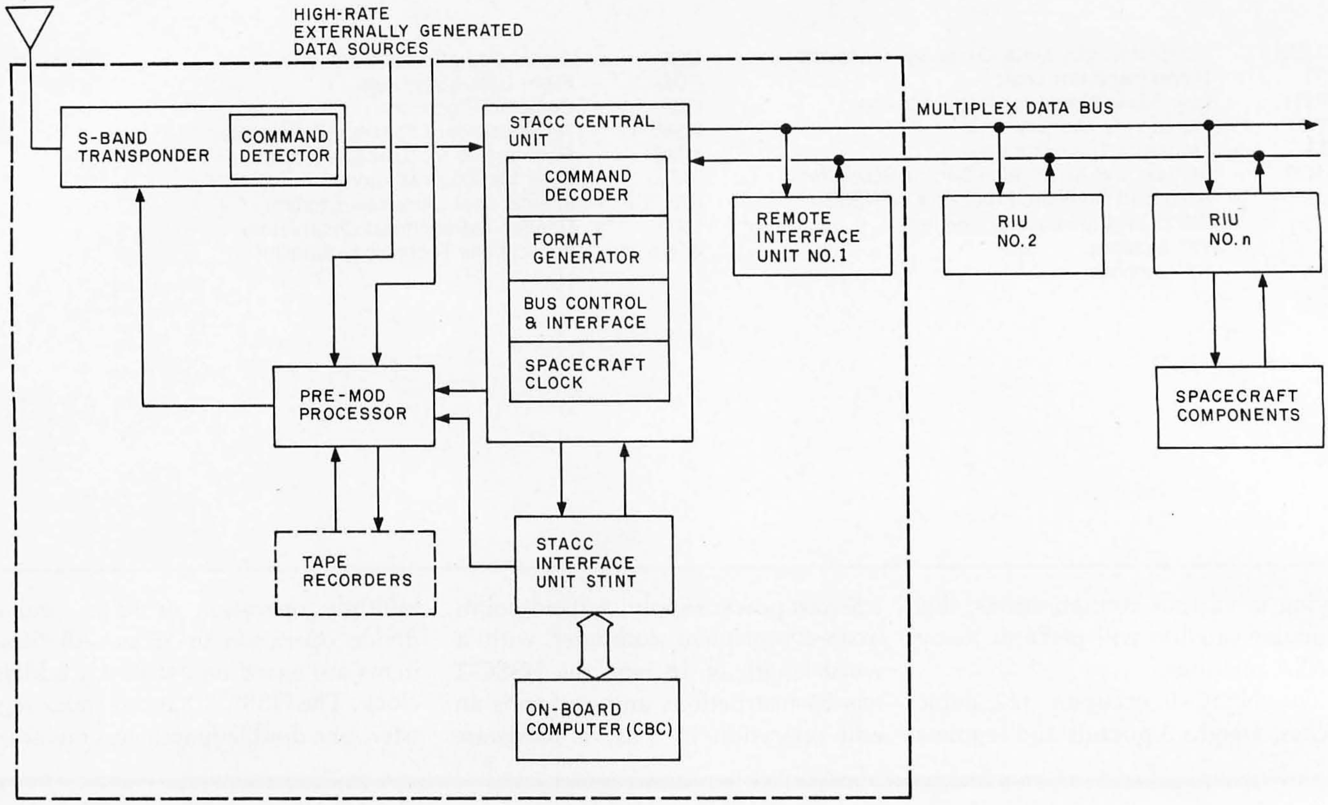

Figure 2: *Simplified block diagram of the Command and Data Handling module of the Multimission Modular Spacecraft.*

and features indirect addressing. It has 16 interrupt levels and handles as many as 16 direct-memory-access devices over a single 100-word-per-second channel.

The addressing range of the NSSC-1 is 64 K words of memory. The NSSC-1 contains memory built of 8 K-word blocks and features paged addressing, by means of which all 4096 words in a given page are accessed directly. Normally, data and code reside in different pages. Dynamic write-protect is applicable to 128-word blocks of memory. Memory units on the NSSC-1 use power switching to reduce consumption of energy when units are not being addressed.

Since the NSSC-1 contains no ROM (read-only memory), the computer has a direct-load feature that allows loading a "cold" machine through the spacecraft command link. By contrast, the Digital Operations Controller on Applications Technology Satellite-6 did have memory-load and "bootstrap" ROM software. Of course, if a ROM contains a programming error, it can't be corrected while in orbit.

Multimission Spacecraft

The characteristics of the MMS (Multimission Modular Spacecraft) impose many requirements on the NSSC-1. The MMS consists of three building-block modules and a supporting structure. The modules—Power, Attitude-Control, and Command and Data Handling equipment—provide ready-made spacecraft components. Combining an MMS with an instrument module makes a spacecraft that the Space Shuttle can launch and retrieve. The first MMS spacecraft to be launched was the Solar Maximum Mission in February 1980. The next is Landsat-D scheduled for July 1982.

Aboard the MMS, the NSSC-1 resides in the Command and Data Handling module as part of the spacecraft data bus. This module contains telemetry transmitters and command receivers for spacecraft operation. The Command and Data Handling module can include as many as three standard 10^8-bit or two standard 10^9-bit recorders for temporary storage of data for the spacecraft or the instruments on board. The Command and Data Handling module also contains the basic timing-reference signal for the spacecraft, accurate to 1 in 10^6 parts and stable to 2 in 10^8 parts per day. Instruments themselves may include more accurate clocks.

The most important component of the MMS data system is the multiplex data bus. The bus is a set of redundant party lines and has both supervisory and reply lines. The multiplex data bus links all components of the spacecraft. The only data that doesn't flow through the multiplex data bus is data transmitted at rates greater than a megabit per second.

Linking each spacecraft component to the data bus is a special interface called a Remote Interface Unit. Since the bus is configured as a party line, each Remote Interface Unit has a unique address ranging from 1 to 63.

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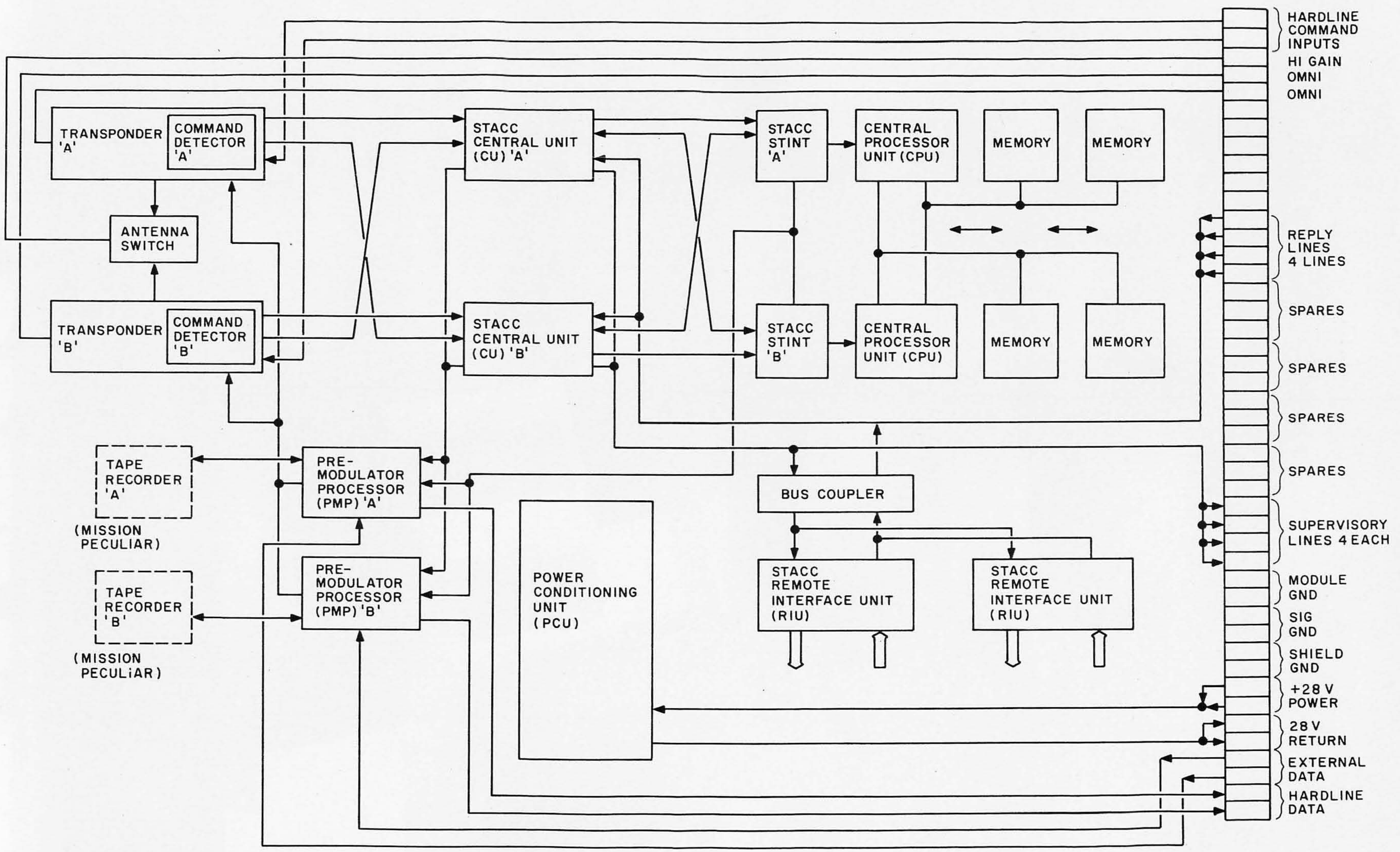

Figure 3: *Detailed block diagram of the Command and Data Handling Module of the Multimission Modular Spacecraft. The diagram shows the module's interface as well as the redundancy of each of the module's components.*

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Each Remote Interface Unit can handle 8 serial-magnitude and 64 pulse-type commands. (In a serial-magnitude command, the whole byte is taken to have one value. In a pulse-type command, each bit is an "on" or "off.") A Remote Interface Unit can also handle 64 telemetry channels. Some spacecraft components have more than one Remote Interface Unit assigned to them.

The bus supervisory lines are time-division multiplexed. They carry command messages and addresses for interrogated telemetry. Four basic message types, each 32 bits long, make up a basic 125-microsecond supervisory-bus timing cycle. Data on the reply bus moves in 8-bit packets. The data bus is basically a 1.024-megabits-per-second serial line.

The STACC (standard telemetry and command components) central unit is the main interface between the spacecraft data bus and the command receiver/transponders, the telemetry modulators/transmitters, and the on-board computer. The on-board computer, however, is not interfaced directly to the STACC but through the STINT (STACC Interface Unit).

Figure 2 shows a simplified view of the Command and Data Handling module. Note that the path for extremely high-rate data bypasses the bus and feeds the telemetry modulators directly. Also note that the optional tape recorders may be used to buffer telemetry data for later transmission to the ground.

Figure 3 is a fuller block diagram of the Command and Data Handling module with all its interfaces. The diagram shows that the Command and Data Handling module contains redundant copies of every component. There are two processors for the NSSC-1, but only one complement of memory. Only one of the NSSC-1's processors can be powered at a time, and either processor can address all of the memory.

So far, as its commands and its contributions to telemetry are concerned, the NSSC-1 is just another component of the bus. Most bus traffic consists of interrogation addresses, commands going out to components, and data for telemetry. The STACC unit, under ROM control, requests telemetry data in a certain format. The NSSC-1 can modify that format if necessary.

When the computer needs certain data faster than it is normally sampled from telemetry, the on-board computer can request and receive the needed data over the bus. Such data is then "interleaved" with telemetry data. One design consideration is to prevent the telemetry formatter and the on-board computer from contending to sample the same device at the same time.

The Future and the NSSC-1

The NSSC-1 is a production-model computer that is adequate for today's missions. Because more and more data-processing tasks are being assigned to the NSSC-1, its adequacy for missions in the 1980s is questionable. NASA is considering several approaches to increase computing power in on-board computers of the 1980s.

In an attempt to avoid complete redesign of a basically adequate component, NASA has investigated several schemes to augment the NSSC-1 within the framework of the current design. These schemes include the addition of floating-point hardware and the off-loading of large computational tasks to dedicated microprocessors.

One study proposes using a microprocessor to collect, format, and process data from the spacecraft's gyroscopes. This task is a time-consuming, repetitive computational burden that could easily be shifted to a microprocessor.

A similar proposal calls for shifting the attitude determination and control algorithm, representing approximately 40 percent of the NSSC-1's computational load, to a dedicated microcomputer. It turns out that the Texas Instruments 9900 microprocessor would be ideal for this application. The input/output from most of the spacecraft's devices is serial and has word sizes up to 24 bits, and the 9900 has an inherently serial input/output structure.

Microprocessors could also relieve the NSSC-1 of several other modular

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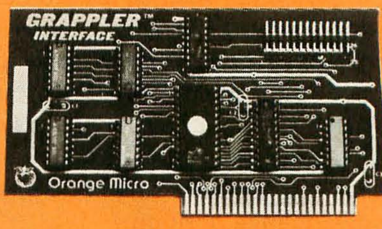

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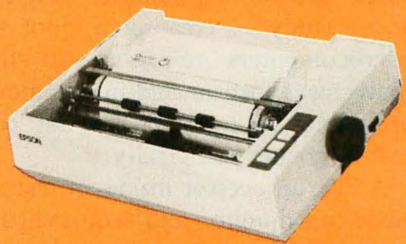

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tasks. One of these is the calculation-of-orbit position. These calculations rely on frequently updated data from the ground and usually involve evaluating long time-series polynomials. Extremely difficult to do without floating-point, calculations of position usually require at least 32 bits of precision, or a 24-bit mantissa and 8-bit exponent. A recent study projected that the on-board computer would be required to perform 1300 floating-point operations per second; 60 percent of the operations were short, such as addition, and 40 percent were long, such as division and multiplication. The NSSC-1 can do only 30 of these computations per second and not in floating-point. (When the Global Positioning System that is described later becomes operational, it will greatly simplify the task of determining position.)

Table 7 compares the performance of the NSSC-1 with that of several current microprocessors. Ignoring word size, the NSSC-1 may be thought of as the approximate equal of a PDP-8 class minicomputer.

Spacecraft Applications

Designers are using microprocessors more and more as dedicated controllers on spacecraft. The current trend is to give each major instrument its own dedicated microprocessor. This is a step toward on-board distributed processing. Another concept under study is creating a pool of microcomputers to serve all the spacecraft's instruments in common, providing extensive backup at the cost of greater complexity.

A microprocessor inside an instrument can monitor and sequence the instrument's operation as well as carry out some first-level reduction of data. Since much of this data reduction is now done on larger computers on the ground, the use of microprocessors inside instruments will greatly reduce the amount of data that must be transmitted from the spaceship to ground stations.

But designers must also weigh the possibility of losing valuable data due to a malfunction of a microprocessor aboard a spacecraft. The specter of a perfectly functioning instrument defeated by a failed microprocessor haunts instrument scientists. Designers must also assure that the support required for the space-borne processor does not become greater than the computer resources required if the job is done on the ground.

Before a scientific instrument can become operational on a spacecraft, scientists must specify the required data-processing algorithm and the format of the output data. Then the processing resources required can be estimated, basically in terms of time and memory. Then a decision can be made as to where the processing can best be done—on the ground or in the spacecraft.

One or more Remote Interface Units connect the microprocessor-based instrument processor with the MMS multiplex data bus. Data rates from X-ray instruments typically carried on MMS spacecraft usually do not exceed 256 k bps (bits per second). Gamma-ray instruments usually result in less data by an order of magnitude.

Techniques often applied in instruments' dedicated processors include: spectral analysis by fast Fourier transform algorithms for two dimensions; time-domain analysis, such as burst detection and periodicity detection; and the detection of transients for modification of instrument operation in real time.

Payloads designed for the space shuttle flights of the 1980s draw heavily on microprocessor technology, often using microprocessors in place of discrete logic and hardwired controllers. In such applications, microprocessors provide an unprecedented level of complexity and flexibility. An example is the Payload Assist Module-Delta Class (PAM-D), a sort of second stage for the shuttle. The PAM-D will boost spacecraft to a final orbit beyond what the Shuttle Orbiter can achieve directly. Several microprocessors aboard the PAM-D will check and cross-check safety features, sequence operations, and interface with the Shuttle's and the payload satellite's data systems.

Global Positioning System

The GPS (Global Positioning System) will consist of a network of orbiting spacecraft that provides global coverage. The GPS is designed to yield highly accurate data about the positions of earth satellites. The GPS satellites and ground stations are also known collectively as the NAVSTAR system.

The experimental model of the GPS receiver to be carried on Landsat-D uses a dedicated LSI-11 processor to calculate position in orbit. Using data received from orbiting GPS spacecraft, the GPS receiver can locate Landsat-D's position within meters on the earth's surface or in orbit. This will enable the satellite to make accu-

Processor	Technology	Word Size	Registers	Cycle Time	Number of Instructions	Add Time	Multiply	Divide	Word Addressing Capability	Temp Range
NSSC-1	TTL	18	3	1.6μs	55	5μs	38μs	75μs	64 K	−10° to +40°C
8080A	NMOS	8	7	1.5μs	91	3μs	—	—	64 K	−55° to +125°C
9900	NMOS (I^2L)	16	16	.333μs	64	4.67μs	17.33μs	30μs	32 K	0° to +70°C
LSI-11	NMOS	16	8	.38μs	74	3μs	70μs	80μs	32 K	0° to +50°C
1802	CMOS	8	16	1.24μs	75	2.5μs			64 K	−55° to +125°C
ATAC-16ms	Schottky	16	16	.250μs	129	.25μs	5.5μs	11.25μs	64 K	MIL Spec

Table 7: *Comparison of on-board computers with microprocessors.*

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rate correlation of its observations with latitude and longitude.

The GPS receiver is a "black box" device—that is, all that the user needs to know about it is the format of data that the GPS receiver accepts and produces. But the processor inside the GPS receiver is basically an LSI-11. The GPS receiver receives coded GPS signals, decodes them, and calculates a position. This position is then transmitted to the user; in the case of Landsat-D, the user is the on-board computer. The Shuttle Orbiters will also be equipped with GPS receivers.

An Apple in Orbit

The shirt-sleeve environment of the Spacelab reduces the stringency of requirements on equipment. For use not critical to the mission, standard commercial hardware can be used. In fact, one of the first Spacelab flights will have an experiment controlled by an Apple II Microcomputer system. The Apple will monitor an experiment in plant growth in the zero-gravity environment and will collect data for recording and transmission. Although the Apple has been adapted for use with other equipment, it is basically the same Apple that is commercially available. The use of microcomputer systems as dedicated experiment controllers aboard spacecraft is expected to increase rapidly.■

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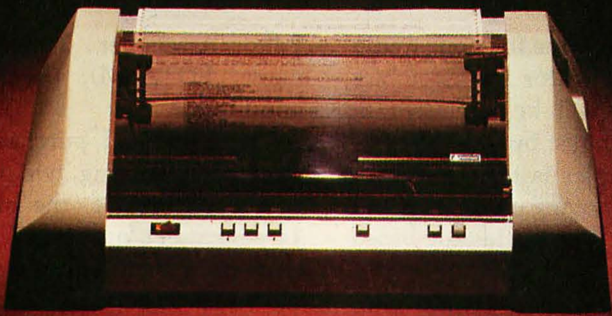

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If you have bought a floppy-disk drive for your Radio Shack TRS-80 Model I and want an editor and assembler package that uses the disk, you will be interested in DISKMOD. The only problem with just buying the disk-based Radio Shack Macro Assembler is the $100 price tag. This expense is particularly annoying if you own and are satisfied with Radio Shack's cassette-tape-based Editor/Assembler.

The DISKMOD program from Misosys Software takes the cassette-based Editor/Assembler and modifies it to reside on disk and to use disk files for most I/O (input/output) operations. You can save about $50 by buying DISKMOD and the Radio Shack cassette Editor/Assembler, or $80 if you have the cassette Editor/Assembler. I am not saying that the Misosys-modified cassette Editor/Assembler is the equivalent of the disk-based Macro Assembler. It isn't. But if you are not doing extensive programming in assembly language, you may not need the extra features contained in the Macro Assembler.

I use Z80 assembly language for writing utility programs and an occasional subroutine, when I need a function that BASIC can't perform with enough speed. Aside from that, all my programming for the TRS-80 is done in BASIC. Since I already owned the cassette Editor/Assembler (hereafter referred to by its file name, EDTASM), the modification program looked good to me.

The package I purchased consisted of a single tape cassette containing two versions of the program (one for EDTASM 1.1, the other for EDTASM 1.2) and a 14-page user's manual. The cassette is warranted for 90 days on a replacement-only basis. (This must be what the registration form is for, since no other explanation of its use is given.)

The DISKMOD program moves the EDTASM program to disk after modifying it extensively. The modifications:

- allow loading and saving source programs and data to a disk file
- allow the object code to be written to a disk file
- allow you to move blocks of source data in the text buffer
- provide a replace-string function for the editor
- allow you to see how much free space is left in the text buffer
- allow you to get a disk-directory listing from EDTASM
- allow you to kill a file from EDTASM
- allow use of the Clear key
- enable you to paginate listings
- let you sort the symbol table before printing it
- change the screen scrolling to provide 15 lines of text on the screen
- allow you to reenter EDTASM without losing the contents of the text buffer
- enhance the B command and the DEFM assembly output

Your next question is, "What do I have to do to use the DISKMOD program?" First, you must have a system with 32 K bytes of memory and a copy of the Radio Shack cassette Editor/Assembler. The DISKMOD program works with either version 2.2 or 2.3 of TRSDOS and with most other TRS-80 disk operating systems.

The instructions for loading and using the DISKMOD program are simple and straightforward. I found only

At a Glance

Name
DISKMOD

Purpose
Upgrade the Radio Shack cassette-based Editor/Assembler to a disk-based Editor/Assembler

Manufacturer
Misosys Software
5904 Edgehill Dr
Alexandria VA 22303

Price
$19.95

Format
Cassette tape

Language
Z80 assembly language

Computer
TRS-80 Model I Level II with 32 K bytes of memory, a floppy-disk drive, and the Radio Shack cassette Editor/Assembler

Documentation
14-page 8½- by 11-inch loose-leaf pamphlet

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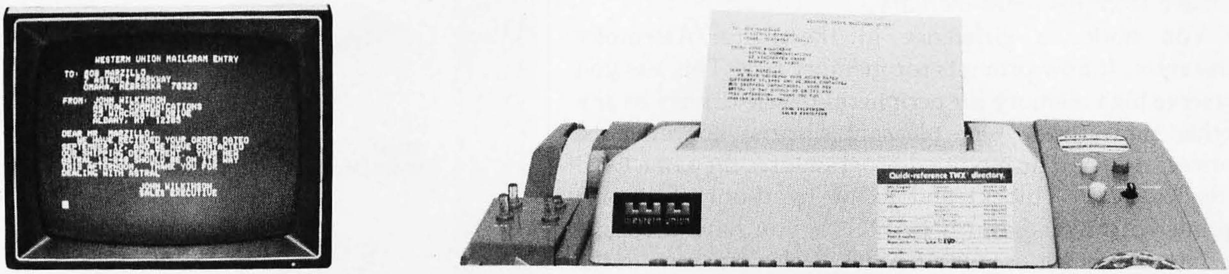

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Listing 1: *Output of the PD (List Directory) command.*

```
00018 FREE GRAINS - DIRECTORY - DRIVE 0 - TRSDOS -09/17/80
TAPEDISK/CMD      00512
LOWER/CMD         00256
COPY/CMD          03072
TEST1/CMD         01536
EDTASM/CMD        05888
RSTERM/CMD        00768
KSRTEST/CMD       00256
```

one slight problem: the command provided to write the DISKMOD program to a disk file is incorrect. It reads:

F DISKMOD/CMD 7500 8ACA 7F70

It should read:

F DISKMOD/CMD:0 7500 8ACA 7F70

With this correction, anyone can use the program successfully. The process takes about ten minutes. When you're finished, you can type the command EDTASM under TRSDOS and have the Editor/Assembler speedily loaded from disk into memory.

You notice a difference in the Editor/Assembler instantly. It now prompts for memory size. This lets you reserve high memory for peripheral-device drivers or any other subroutines. One pleasant surprise concerns the printer driver. The modified program uses the same DCB (device control block) and ROM (read-only memory) printer driver as Level II BASIC. If you have a special printer driver for use with BASIC, it also works with the Editor/Assembler. When you have answered the memory-size question, you are back in normal working mode.

The only command I will mention is the PD, or List Directory, command. It gives the name and size of each normal file on the disk, as well as the amount of free space on the disk. This information is particularly useful when you are attempting to squeeze a new file onto a nearly full floppy disk. Listing 1 shows a sample of the information you receive.

The other new commands work quite well. Explicit prompts are used for most of them, making it easy for the beginner to use them. The manual explains each new command in detail and notes any changes made to the standard commands by the DISKMOD program.

The package works as advertised and all the commands function. It is possible that some problems will occur as I use the modified Editor/Assembler more extensively. In my experience, major modifications made to an existing program generally cause some minor bugs. The modified program has worked satisfactorily so far.

If you are considering a move to a disk-based Editor/Assembler, but dislike the cost of Radio Shack's Macro Assembler, I strongly recommend the combination of the Misosys DISKMOD and the Radio Shack cassette Editor/Assembler programs.■

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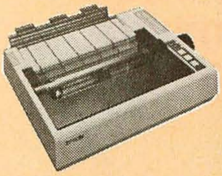

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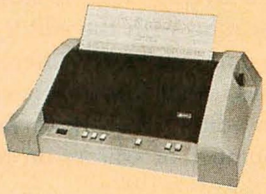

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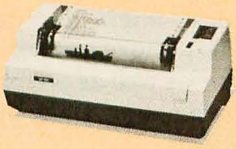

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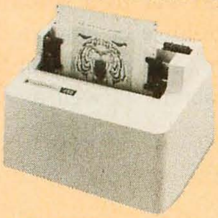

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Software Review

MINCE
A Text Editor

Christopher O Kern
201 I St Apt 839
Washington DC 20024

A text editor is probably the most personal program on a personal computer system. The average user spends a good amount of time communicating with the editor—entering or altering programs, data, or text. Different users, with different applications, often have different ideas about how they want an editor to work, a fact which accounts for the large number of editors on the market.

MINCE is one of the newer entries into the software market for 8080-family computers that use the CP/M operating system. MINCE is modeled on a large-system editor, called EMACS, which was developed at MIT (Massachusetts Institute of Technology). Its authors say that MINCE stands for "MINCE Is Not Complete EMACS"; nevertheless, it has a lot to offer. It can do all the usual text-editing functions—insert or delete characters, words, and blocks of text, move text around, and search for and replace strings—as well as perform a number of other operations that are not generally available in microcomputer editors.

MINCE's features include the ability to read, create, and write multiple-disk files, to move text among different files quickly and easily, to automatically transpose characters and words, and to execute familiar operations in unusual contexts. For example, it can move the cursor by sentences or paragraphs, fill lines out to a specified length one paragraph at a time, capitalize or change the case of words without retyping them, and delete just the whitespace between words or characters as well as the words or characters themselves.

Command Structure

Despite the large number of commands in MINCE, the editor functions coherently. Command types are grouped logically so that one command sequence is used for a group of commands that affect *textual* units such as letters and lines, and another command sequence is used for a group of commands that deal with *lexical* units such as words and sentences. Where possible, the same mnemonics are used for similar operations at these different command levels. For example, the command to move the cursor forward one letter is Control-F, and the command

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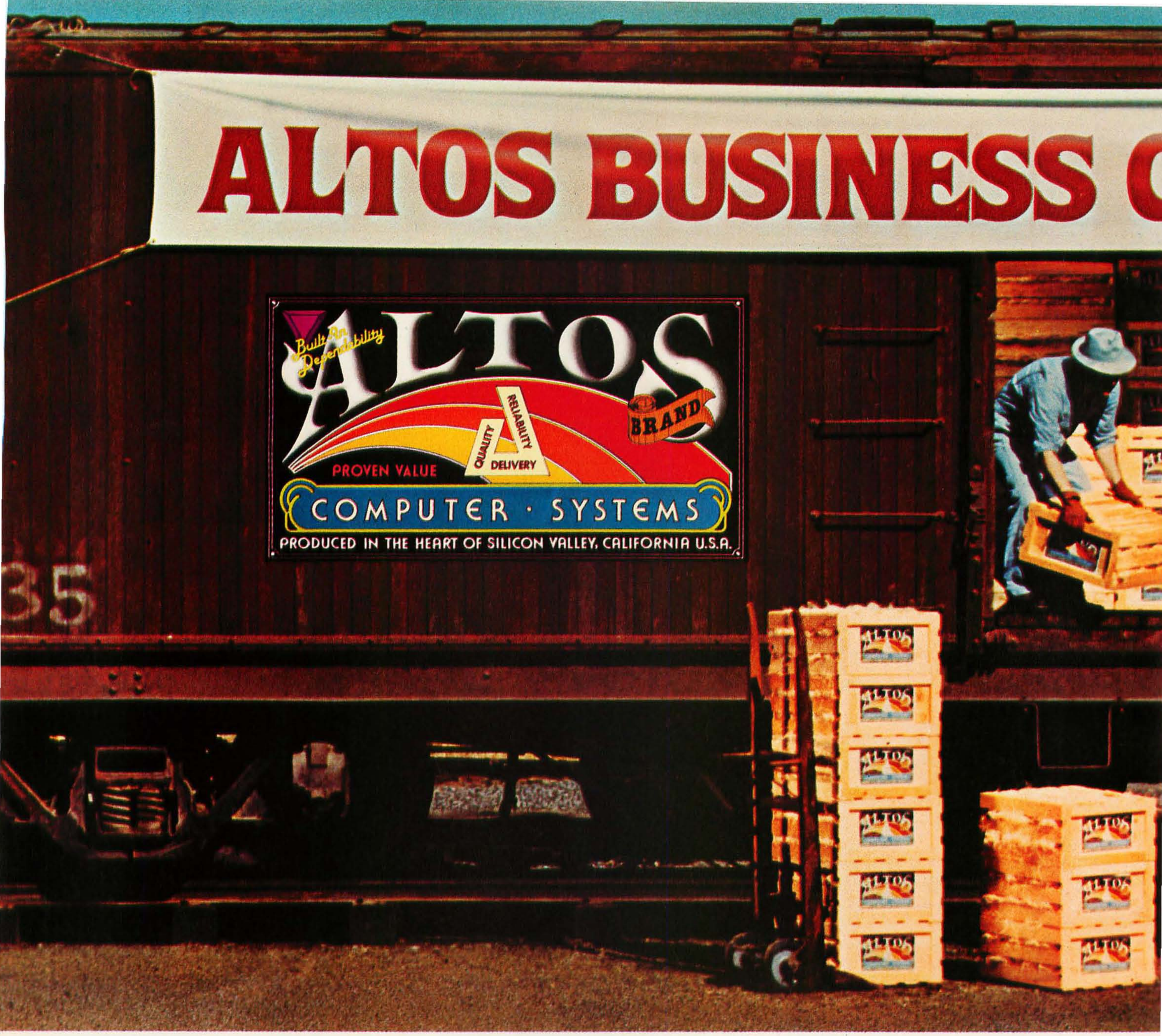

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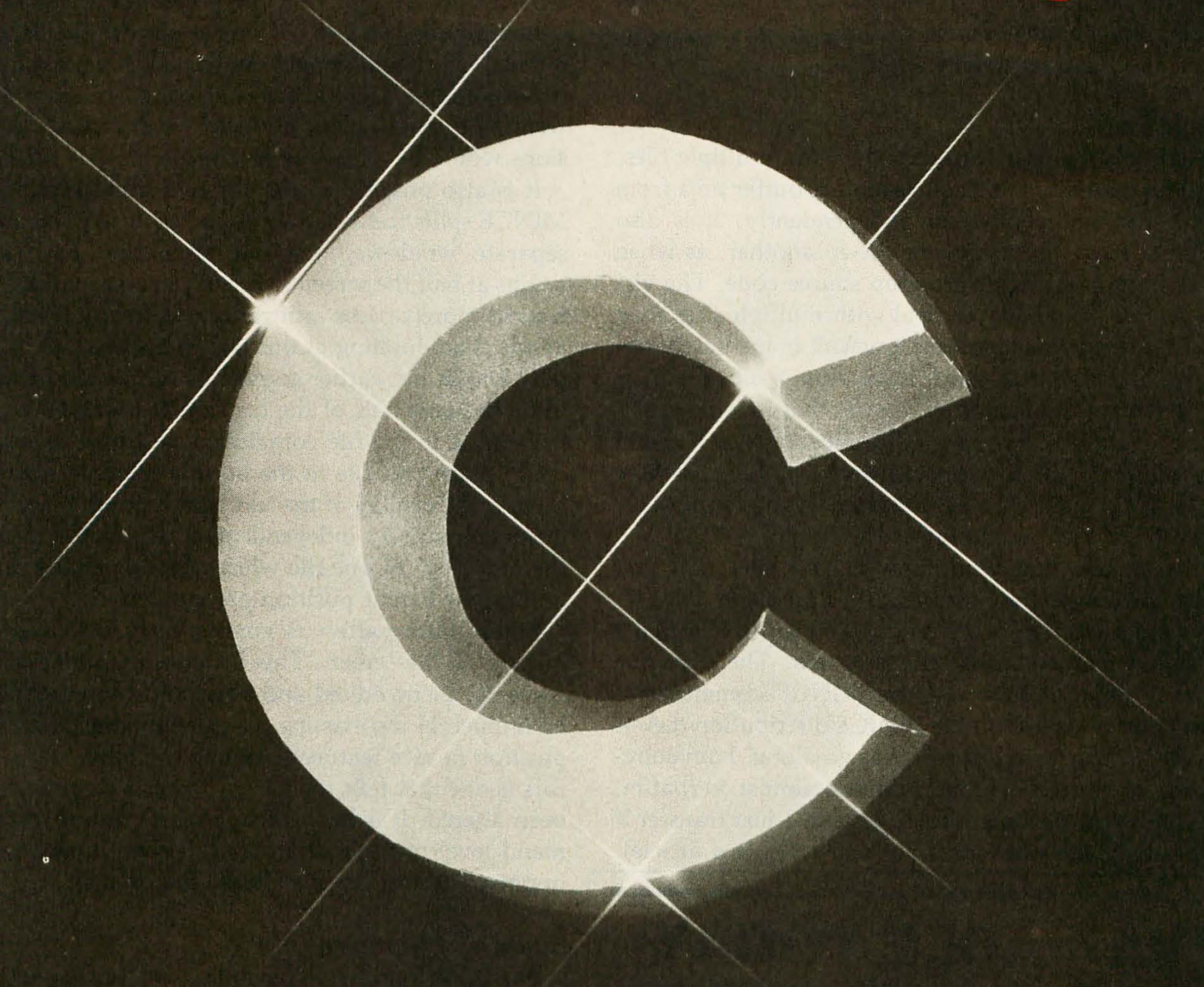
to move it backward one letter is Control-B, while the analogous commands to move the cursor across words are Escape-F and Escape-B.

As the previous example implies, MINCE does not use the cursor control or other special function keys available on many terminals. Commands are entered as control characters, as escape sequences (the escape character followed by one or more additional characters), or as *control sequences* (a control character followed by another control character or a printing character). Most commands can be executed reiteratively by preceding them with a numerical argument. In the usual operating mode, text is self-inserting: characters typed at the console will be inserted into a file rather than written over what is already there. An optional *page mode* provides the more common arrangement in which typing at the console replaces any text at the current cursor position.

For convenience, the text being edited is assumed to contain only a single "newline" character between lines. While this character is displayed only in the sense that it moves the text following it down to the next line, it is otherwise treated in the same manner as any other character. But the files written by MINCE conform to the CP/M convention of having both an ASCII (American Standard Code for Information Interchange) carriage-return character and a line-feed character at the end of each line. Thus they are completely compatible with other CP/M programs, such as the CP/M-resident TYPE command. MINCE will display control characters embedded in the text except for those, such as newline and tab, to which the text editor responds. Control-A, for example, would appear on the display as ↑A.

MINCE provides some rather arcane commands, such as one that moves the cursor to the next line and indents it to correspond with the indentation that started the previous paragraph (helpful for writing code in struc-

SuperSoft's Optimizing



for CP/M

The SuperSoft "C" compiler supports most of version 7 Unix standard "C". Several special and widely desired features are supported, including:

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- Include files using the **#include** statement.
- Inline assembly code is supported with the **#asm** and **#endasm**.
- The object code may be ROMed.
- Programs may be ORGed for any location.
- Completely **dynamic memory allocation** is supported, both by the compiler and in user programs. (That is, the functions 'alloc' and 'free' are provided with the compiler.)

SuperSoft "C" is a two pass compiler. The first pass of the compiler produces an intermediate code (U-code, for Universal code). Pass two contains both the translator and the optimizer. The intermediate code is optimized and assembly code is output to file.

The optimizer typically results in 40% code reduction. This means that compiled object code will run nearly as fast as that which was written in assembler.

An important feature of the compiler is that aseembly code is produced. This means that "hand optimization" of critical sections is possible. Also, the inline coder allows easy insertion of assembly language routines.

With the compiler comes the complete source code to the I/O libraries. These libraries are equal to or better than any that exist for the 8080/Z80 computer system. Functions included:

open	close	read	write
seek	tell	fopen	create
putc	getc	flush	

The Seek command supports absolute, relative from front, and relative from end of file. Fopen includes fcreat. Also included with the compiler are numerous sample programs and a complete library of useful functions.

Compile time options include listing file, console output, syntax checking and others.

Requires: 48K CP/M, (more recommended)

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tured programming languages). Yet it is possible to make MINCE do useful work by learning only a handful of the most common commands and picking up others as your sophistication and requirements grow.

Multiple Files

MINCE lets the user work on, or from, multiple files. Each file is read into a logically separate buffer area from which it can be operated on independently. It is also possible to move text from one file to another, as when copying blocks of text or program source code. The virtue of having the ability to deal with multiple files may not at first be obvious (at least it wasn't immediately obvious to me), but, now that I have done a bit of experimenting with multifile editing, I think that I would really miss that feature. Of course, ignorance is bliss: it didn't bother me that I could work on only one file at a time when I was using CP/M's ED program or any of the other editors I have used at one time or another.

As I write this, I am working with three files. The first contains the text you are reading at the moment. The second contains random observations about MINCE that I entered as I learned to use the program. The third file contains a description of all the MINCE commands—conveniently provided on the MINCE distribution disk—that I keep ready for reference. As I go along, I am copying some of my earlier observations almost verbatim. After editing the pertinent block of text, I just transfer it into the main file (the one I am using for this article). When I am finished writing, I will save the article on disk, replace the original random observations file with the edited version, and do nothing at all with the list of commands, which will remain on the disk in its original form. If I wanted to, I could save the edited random observations as a new file, so both the original and edited versions would be available on the computer's file system.

It is also possible to display two files simultaneously. MINCE splits the video screen horizontally, creating two separate windows, one into each file. Each window begins at half the screen size, but can be expanded or contracted more or less arbitrarily. At the moment, for example, I am looking at this text in the top half of the display and at my earlier comments on the use of windows in the bottom half of the display. If I wanted to look at something in the file containing the list of commands, I could place that file in the bottom window without disturbing the display of the text I am writing. Since the windows are entirely independent, it is possible to move to the next page of one file while writing, editing, or maintaining the cursor position on another.

Status information is continuously displayed at the bottom of the screen. This includes the name of the file currently being edited and a percentage figure indicating how much of the existing file is behind the current cursor position (a nice feature). Among the other status indicators is one that tells the user whether a particular file has been altered. If it has, MINCE won't return to the command level of the operating system without offering an opportunity to save the altered file on disk.

Speed of Operation

For all its impressive flexibility, MINCE is not without its flaws, some of which it shares with other editors running in microcomputer environments. First, and worst of all, MINCE is slow. The editor doesn't seem to lose characters; frequent checking for keyboard input and the presence of a large type-ahead buffer ensure that. But MINCE can't update the screen fast enough to keep up with a fast typist. It took me quite a while to get used to the fact that one or more characters I had typed, especially when I was using multiple deletes to backspace/erase to an earlier point on a line, had already been entered in the file, but were still waiting to appear on the screen. There are commands in MINCE's repertory that I can use to get around this particular problem. But I expect characters to appear as soon as I type them, and MINCE simply can't accommodate me.

MINCE is also slow in performing certain updating functions. For example, it starts a new "page" after the user types past the last visible line on the screen. Many other editors simply scroll the previous text up one line, which is simpler than removing a whole page and replacing it with a new one because scrolling can be performed by the terminal hardware. All the editor has to do, then, is keep track of which lines are still visible on the screen. You can keep typing while MINCE figures out what to do next, and anything you type will eventually be displayed. But it may take several seconds before that happens.

Reference the Future...

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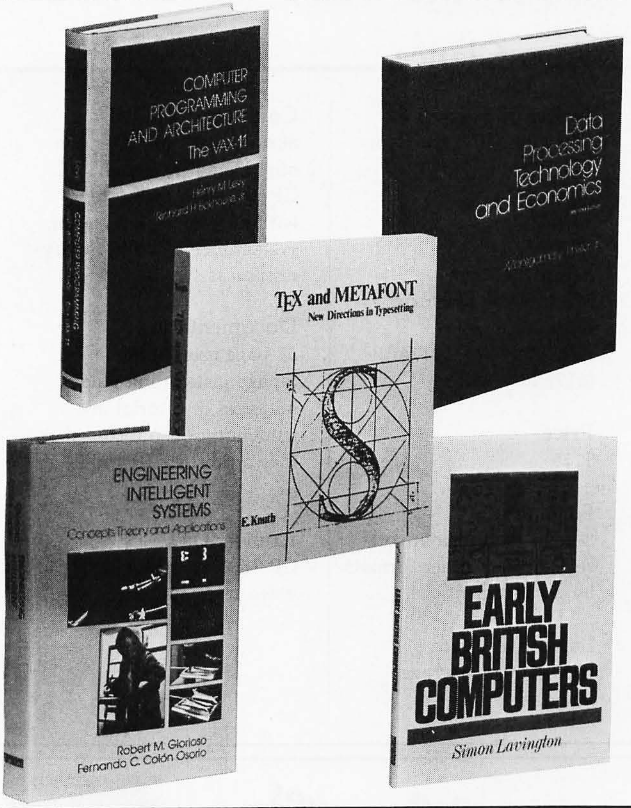

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ENGINEERING INTELLIGENT SYSTEMS: Concepts, Theory, and Applications
Glorioso *and* Colón Osorio
From fundamentals through advanced industrial applications, this book brings together the key elements for designing safe, practical, cost-effective intelligent systems.
1980, hardbound, 472 pages, $27.00

PROJECT WHIRLWIND, The History of a Pioneer Computer
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The technological traditions, the research and development policies and practices, the funding crises, and the management techniques that went into this innovative engineering triumph.
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TECHNICAL ASPECTS OF DATA COMMUNICATION
McNamara
A practical approach to the nuts-and-bolts problems and solutions in configuring communications systems.
1977, hardbound, 387 pages, $26.00

TEX and METAFONT, New Directions in Typesetting
Knuth
Details TEX, a technical typesetting system, and METAFONT, a system for the precise design of alphabets. (Co-published with American Mathematical Society)
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I suspect the slowness is a by-product of two of MINCE's undeniable virtues: the way it was written and the way it updates the screen. MINCE was written in the high-level language C, a general-purpose language developed at Bell Laboratories that is often used for system-level programming (see "The BDS C Compiler" by Christopher Kern in June 1981 BYTE, page 356). Since it is written in a high-level language rather than in an assembly language, MINCE is easy to transport to other processors. This portability means that as long as MINCE's authors stay in business, someone who buys new hardware is likely to be able to buy a version of MINCE to run on it. (Perhaps those responsible for MINCE will publish their source code if their business goes under.) But the use of a high-level language on an 8-bit microcomputer inevitably imposes a considerable penalty in speed.

To update the screen, MINCE uses standard cursor positioning facilities rather than the idiosyncratic hardware page editing capabilities available on some smart terminals. This means that the editor will run on just about any terminal or stand-alone computer system available. It takes time, however, to move a cursor around and to update a display serially, even if the terminal is running, as mine is, at 9600 bps (bits per second).

Text Swapping

Another problem with MINCE is that it swaps parts of the file between main memory and disk during long pauses between keyboard entries. In the long run, this is to the user's advantage: performing this operation while

At a Glance

Name of Software
MINCE (MINCE Is Not Complete EMACS)

Type
Text editor

Manufacturer
Mark of the Unicorn
POB 423
Arlington MA 02174
(617) 489-1387

Price
$125

Format
8-inch, IBM format soft-sector disks; other formats by arrangement

Language Used
8080-family machine language

Computer Needed
8080-family computer running Digital Research's CP/M operating system with at least 48 K bytes of system memory and floppy-disk mass storage

Documentation
52-page user guide;
5-page installation guide;
46 pages of tutorial introduction (also included as files on distribution disk)

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CP/M users requiring a video terminal text editor

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the keyboard is inactive means that less disk swapping will be necessary at a time when the user is more active and when text swapping would really slow him down. But even though each swapping operation only takes about a second, I found the sudden onset of disk activity disconcerting. Fortunately, MINCE's configuration program allows the user to set the time delay between the last keyboard entry and the start of the swapping operation. MINCE's authors recommend a four-second pause. I found a twenty-second delay more to my liking.

MINCE is a large editor not only in the number and variety of its available commands, but also in its requirements for disk space. The editor proper requires 30 K bytes. During operation, MINCE must have a *swap file* available to provide space for those portions of the file(s) being edited that don't fit in the host system's available semiconductor memory. MINCE's authors say a 24 K-byte swap file is the workable minimum and recommend a 64 K-byte swap file. I evaluated MINCE and wrote this review using a 32 K-byte swap file with no serious effects, although I did have to juggle my reference files as the article grew in size. (Files not currently being used can be dropped, thus freeing space in the swap file for active files.)

Configuration and Documentation

Selecting the size of the swap file, notifying MINCE of the characteristics of the host system's terminal, and other required set-up operations are performed by a configuration program that is very easy to use. The configuration program comes equipped with the necessary information for the terminals most commonly encountered in microcomputer systems, and it accepts user-supplied information for the less common ones. The whole configuration process is menu-driven and provides ample opportunities to correct errors or simply change one's mind.

MINCE's documentation is excellent. The user manual is well organized and crisply written. In addition, two tutorial introductions to MINCE are supplied. One is designed for more experienced programmers, and the other is designed for the uninitiated computer user. In practice, I think the programmers' tutorial would suffice for anyone who has ever used a text editor on a computer. The general-users' tutorial claims to require nothing more than knowing how to type and how to log onto the host computer system—a claim that appears to be true. The first eight-page lesson introduces the trainee, step-by-excruciating-step, to such mysteries as how to use the delete key to erase the previous character, how to move the cursor forward and backward, and how to quit the editor when he is finished. (But, it does not explain how to write a file to disk—that is left for another lesson).

The tutorials don't pretend to cover all of MINCE's features, but anyone who is willing to work his way through them will certainly learn how to use the editor in at least a minimal fashion. Most of the tutorial material is provided on disk files as well as in hard-copy form, and many of the exercises call for the user to edit the tutorial he is working from. I found some of the prose in the tutorials a bit cloying; the exercises provided a convenient remedy.

Conclusions

- MINCE has a large, well-planned command repertory. A user needs to learn only a small subset of the available commands to operate the editor; others can be learned as his requirements grow.
- MINCE permits multiple files to be viewed and edited—a real convenience. Two files may be viewed simultaneously on a split screen.
- MINCE is slow in updating the video display, both during user input and during cursor movement across pages (video screens). The use of a swap file also slows editing down and results in unexpected disk activity.
- MINCE is well documented. Tutorial introductions to the editor help even the novice get started easily. ■

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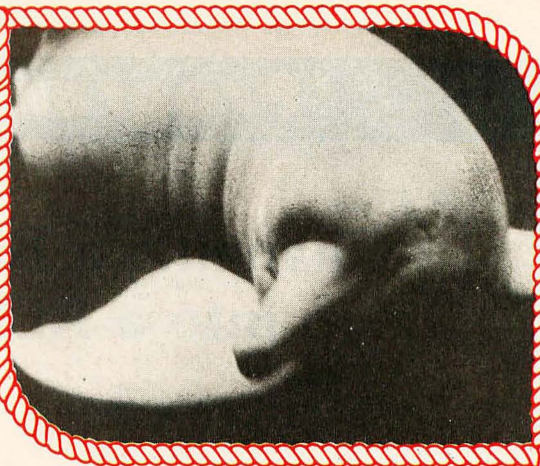

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Changing a BASIC FOR . . . NEXT Loop into a REPEAT . . . UNTIL Loop

James A Maiorana
c/o BYTE Publications
POB 372
Hancock NH 03449

When you program in BASIC, it is often necessary to construct the functional equivalent of a REPEAT . . . UNTIL loop. To do this, many programmers try using a GOTO statement, but, in long programs, many GOTOs make the program run slowly. A FOR . . . NEXT loop, however, can be modified to provide the desired function, without any GOTOs. In many BASIC programs, executing a GOTO means searching the program text to find the correct line number, whereas finding a FOR . . . NEXT loop is done directly by a pointer. I use the following technique in Apple BASIC, and find that it works correctly and produces faster-running programs.

In the following examples, *loop-body* is a block of code and *condition* is an arithmetic expression. Ordinarily, *condition* will be a Boolean expression with 0 equivalent to false and 1 to true.

The first construct uses a dummy variable D:

```
10 FOR D = 0 to 1
20 loop-body
30 D = condition
40 NEXT D
```

This code has precisely the same effect as:

```
REPEAT loop-body UNTIL condition
```

Here is an example of the technique:

```
10 FOR D = 0 TO 1
20 INPUT " GUESS MY NUMBER ", G
30 D = ( G = M )
40 NEXT D
```

This program continues to ask for a number G until G is equal to an internal parameter, M. Here *loop-body* is line 20, while *condition* is the logical expression (G = M) . When G is not equal to M, line 30 sets D to 0. Line 40 increments D to 1, and branches back to line 10. When G equals M, line 30 sets D to 1. Line 40 then increments D to 2, and the loop terminates.

This code may have to be modified for your system. A quick survey of several BASICs showed that some interpreters return a value of −1 in the variable D when the condition in line 30 is met. (TRS-80 Level II and Texas Instruments BASIC give a −1 for true logical comparisons, while Applesoft, Integer, and Atari BASIC give a +1.) Modifying line 10 to allow for this results in an equivalent REPEAT . . . UNTIL function:

```
10 FOR D = 0 TO −1 STEP −1
```

One of these techniques should work on your BASIC interpreter. ■

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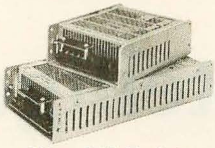

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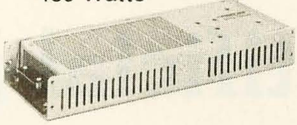

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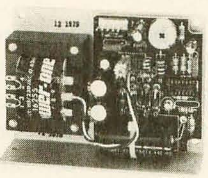

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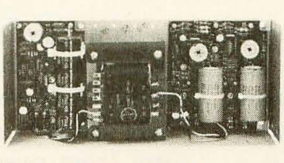

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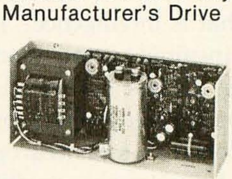

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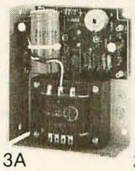

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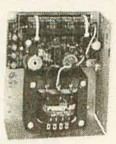

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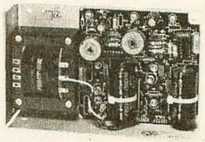

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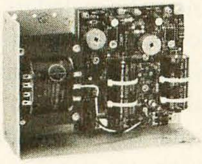

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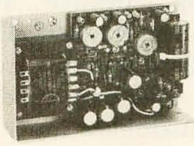

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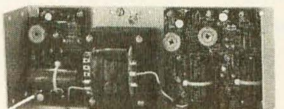

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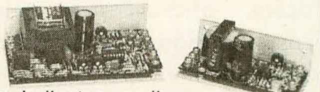

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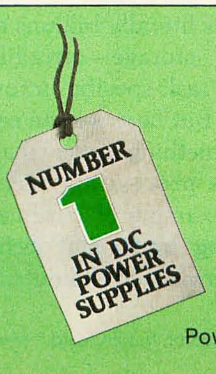

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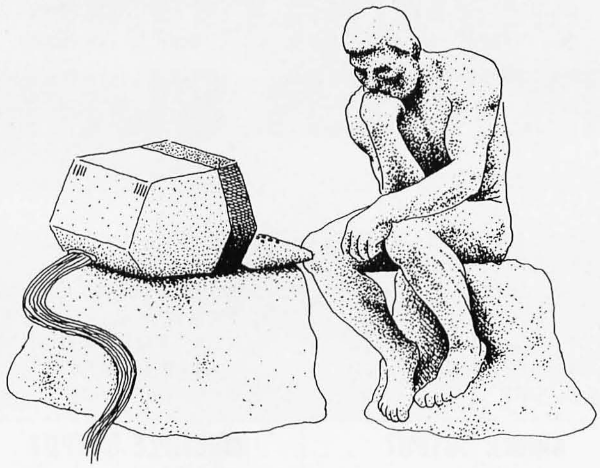

Artificial Intelligence

Steven K Roberts
5885 Dublin Rd
Dublin OH 43017

What is intelligence? This question has inspired great works for centuries. It has furrowed the learned brows of philosophers, psychologists, theologians, and neurophysicists as they have sought, in different ways, to find the answer. Until recently, the question has remained more or less outside the domain of technology. Only in science fiction has the notion of intelligence applied to machines.

But man is a restless creature—thanks to his intelligence—and has a remarkable propensity for tool-building. The physical limitations of the human body are overcome daily with the use of man-made tools: bulldozers, microscopes, telephones, pens, and thousands of other devices. Very near the top of any list of tools must be the computer.

Computers, as most people know and love them, are hardly worthy of the term "intelligence." At best, they are fast and reliable (but abysmally stupid) machines that take very precisely defined tasks and tirelessly perform them over and over. This, of course, makes them invaluable in a fast-paced technological society such as ours, for we have become addicted to freedom from boring repetitive mental drudgery. (When was the last time you calculated a square root the old-fashioned pencil-and-paper way?) But for all their usefulness in assisting our many and varied efforts, computers are still absolutely uninspired contraptions.

Simply providing access to the large body of knowledge now available is a great problem.

In addition to being incurable tool-builders, mankind also has a passion for information—lots of it. There seems to be no end to the exponential growth of human knowledge (it's currently expanding at the approximate rate of 200,000,000 words per hour). On countless subjects ranging from the weather to the ills of our flesh, from computer design to the technology of war, mankind has accumulated such masses of information that only the narrowest of specialists in any field can truly claim to be an expert.

This, however, creates problems, because now that we have all this information, we need to use it. The obvious difficulty is simply providing access to such a large library of knowledge: a person attempting to locate one small fact can easily become bogged down in searching if the library is not extremely well organized and cross-referenced. A less obvious problem is the continual addition of new knowledge to the library without creating a nightmarish jumble of patches and outdated material.

The sheer quantity of information involved in such an effort cries out for a computer solution. After all, hardware can be purchased off the shelf that provides literally billions of words of data storage—certainly enough for most "task-specific" information domains. But here we can see the need for something other than traditional data-processing techniques. (For an example of information storage using traditional techniques, see "Information Unlimited:

About the Author

Steven K Roberts is a free-lance writer and microprocessor-systems consultant living in Dublin, Ohio. He is the author of Micromatics *(published by Scelbi Publications) and* Industrial Design with Microcomputers *(to be published in early 1982 by Prentice-Hall).*

Research for this article included attendance at the First International Conference on Artificial Intelligence, held at Stanford University in August 1980.

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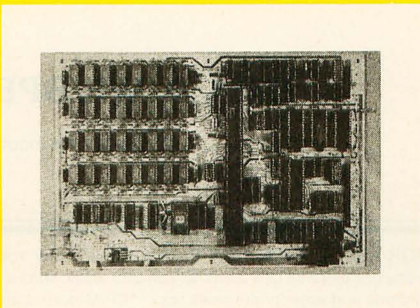

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The Dialog Information Retrieval Service," by Stan Miastkowski, June 1981 BYTE, page 88.)

Types of Knowledge

Knowledge about almost anything can be split into two major classifications: factual and heuristic. Factual knowledge is the most obvious and needs little elaboration; it's often called "textbook knowledge." The heuristic variety, on the other hand, is a little harder to store in a computer. It is the network of intuitions, associations, judgment rules, pet theories, and general inference procedures that, in combination with factual knowledge about a field, allow mankind to exhibit intelligent behavior. (Further muddying the programming waters is a higher level of knowledge that can be included within the heuristic category: "metaknowledge," which is concerned with general problem-solving strategy and such esoterica as awareness of how to think.)

Factual knowledge has been resident in computer systems for decades. Business systems containing records of customer, personnel, inventory, and accounting data typify the rather pedestrian uses to which the majority of large systems have been relegated. If most of the world's computers suddenly became self-aware, they would be terribly bored with their fates.

Heuristic knowledge is substantially more difficult to represent in a program or data base than simple factual data. But any system that is intended as a sophisticated information resource must, in some fashion, incorporate this higher level of knowledge, if for no other reason than to reduce the problem of finding a given piece of information to one of manageable proportions.

Suppose, for example, that a system were created to provide physicians with clinical advice about certain infectious diseases. A mere listing somewhere in the computer's mem-

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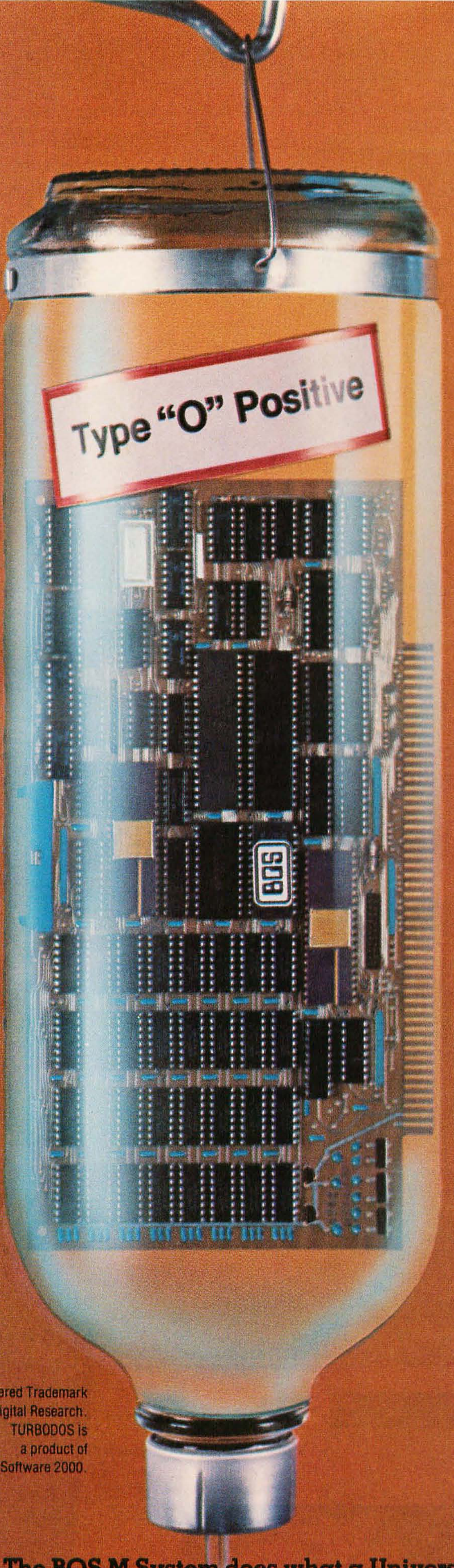

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ory and storage of all the known facts is essentially useless—the only way one could make use of the data would be the simplistic matching of a set of symptoms against sets of indications for each disease.

This kind of approach is doomed from the start: some symptoms are less suggestive of certain diseases than others. Therefore, the system should have the ability to order specific additional tests (giving preference to noninvasive ones) before attempting a diagnosis. Also, the patient's age, environment, and medical history must be taken into account. Amidst all this, there must be the capability of ignoring certain facts if they are inconsistent with the most strongly suggested diagnosis—a patient's tennis elbow, for example, is probably unrelated to his or her infectious meningitis.

If the machine is to be more useful than a textbook, it must be able to do all these things, as well as provide a facility for updating its own information as often as required. In summary, it must possess a measure of intelligence.

Such a system is not mere conjecture, by the way. One has already been created to provide diagnosis and therapy selection for two major types of diseases: blood infections and meningitis. Developed at Stanford University by doctors Bruce Buchanan and Edward Shortliffe, the program, called MYCIN, has outperformed human diagnosticians in the identification and treatment of diseases in this class, not only through its accuracy in pinpointing the pathogen, but in its avoidance of overprescribing treatment.

This last accomplishment is especially noteworthy, because the standard clinical approach to an unknown disease involves a broad-spectrum antibiotic attack on a wide variety of possibilities. This not only exposes the patient to potential toxic effects, but encourages the development of drug-resistant bacterial strains. (A recent Stanford University study revealed that one of every four persons in the United States received penicillin under a doctor's orders in 1977 and that nearly 90% of these prescriptions were unnecessary.)

A Technology Is Born

For all of these reasons, along with many others ranging from the inadequacy of standard programming techniques to the sheer joy of research, computer science has spawned a new discipline: artificial intelligence (AI).

Actually, AI is not all that new: some of the foundations that underlie today's work were laid in the late 1940s and early 1950s by Alan Turing, whose "imitation game" (today called the "Turing Test") is still considered a valid method for determining whether or not a machine is intelligent. In essence, the Turing Test consists of an interrogator communicating via teleprinters with a human and a computer. The interrogator can attempt in any way possible to determine which is which through conversation over the communication links.

At first glance, it might seem that the examiner could easily tell the difference by asking such questions as, "What is 35,289 divided by 9117?" The human would presumably chew on it for a while, and the computer would instantly spit back an answer correct to twelve digits. The flaw in this kind of thinking is that the human might have an electronic calculator in his pocket and the computer, if indeed intelligent (and devious), might give a slow and erroneous answer just to fool the interrogator. Also, the computer might be unable to calculate as rapidly as we would expect, since much of what we call intelligence involves the storage of information in a relatively abstract and very symbolic form. It is possible that such a machine would have to go through a set of thought processes not markedly different from ours to do mathematical calculations, though for the sake of convenience, it would probably have a built-in "calculator."

Turing's work in this area was strangely prophetic and, for the conservative 1950s, somewhat radical. He wrote, "I believe that at the end of the century the use of words and general educated opinion will have altered so much that one will be able to speak of machines thinking with-

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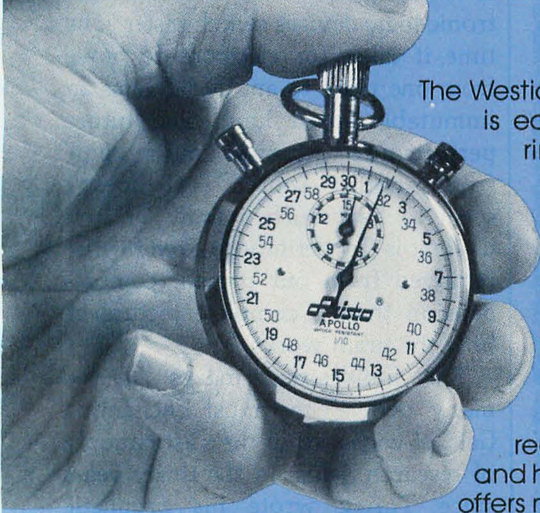

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out expecting to be contradicted."

Once again, technological progress is ahead of schedule—maybe. One of the distinguishing and provocative features of AI is that newer and ever more complex problems lurk behind each breakthrough. Most technologies reach maturity when progress becomes asymptotic: continued effort brings us closer and closer to the limits of what is possible but at an ever slower rate. (An example of this is the ongoing effort to make electronic logic devices switch faster. The time it takes for electrons to move from one place to another defines an immutable speed limit, and future performance increases must come from another source.) AI doesn't seem to have such a limit, or if it does, it is (by definition) even further removed from our present comprehension than a complete picture of how the brain works.

This limitlessness makes AI, for many people, the most enchanting field of endeavor in the vast panoply of research fields. In the thirty years since Turing wrote his prophetic words, AI has grown from an esoteric part-time pursuit of a few visionaries to a full-fledged science, replete with subspecialties, societies, annual international conferences, and journals. Its existence is beginning to be felt outside academia, and in a few years, the computer as we know it is likely to be dramatically transformed.

Work in Progress

There are a number of robust subspecialties in the world of artificial intelligence, dealing not only with various applications but with several problems that must be simultaneously overcome for the dreams of Turing and many others to be fullfilled. The two central problems are so closely intertwined that they can be discussed together: knowledge representation and natural language.

Consider the following conversation:

He: "Hungry?"
She: "I have a coupon for McDonald's."
He: "Have you seen my keys?"
She: "Look on the dresser."

There are some very sophisticated information-processing operations going on here. In this dialogue, most of the real meaning—the real communication—is not explicitly stated. He opens by inquiring whether she is hungry and, in the process, is probably implying that he is hungry as well. She processes this and issues a very cryptic response. Not only does she inform him that she is either hungry or willing to go along for a ride, but also suggests a specific place to eat and, further, hints at economic realities by weighting the selection of a restaurant on the basis of a discount coupon. Her statement assumes that he will understand what a coupon is as well as what a McDonald's is. His next question indicates even deeper communication: he has agreed with her about the choice of restaurant and suggests a specific mode of transportation. This suggestion, however, is made in a roundabout fashion: he asks if she knows where his keys are at the moment, assuming that she knows not only what keys are but that they are linked *with* transportation. She, of course, understands that the keys he's talking about are those of his automobile and suggests a course of action that will solve the transportation problem—correctly assuming that he will not only know which dresser she means, and that a dresser is a piece of furniture, but that he will deduce that the keys must be there.

The implication is that communication between two people involves substantially more than the lexical meanings of the words. The conversation above would not have been so succinct if he had approached a stranger on the street with the same question. The difference suggests the existence of a special relationship between he and she: they share certain aspects of their internal models of the world.

This highlights a crucial truth: language has to be considered as only one part of a much more complex communication process, one in which the knowledge and states of mind of the participants are as much responsible for the interpretation of verbal utterances as are the words from which those utterances are formed. As a conversation progresses, the internal state of each participant continually changes to represent the modified reality that is the result of the communication.

(Frequently, problems occur between people when their respective internal models of the world differ sharply. "I had to work late," can be interpreted in a drastically different way from that intended by the speaker.)

When one attempts to build an intelligent machine, the complexities introduced by this larger view of communication can be surprising. Early systems were developed without a clear awareness of the problem and were constructed of a stored body of facts with associated keywords that were used (eg: Joseph Weizenbaum's ELIZA program) to scan the input messages. Whenever there was a match, sets of specific rules were invoked to produce a response based on both the system's knowledge and the keywords it had located. No attention was given to the actual meaning of the sentences, just to the presence of certain words. Such systems quickly fail the Turing test.

As time went on, it was recognized that the communication problem is interwoven with knowledge itself. In the mid-1960s, programs were developed to translate input sentences into an internal formal language that, theoretically, would allow the system to perform inferences without needing to handle all the subtleties of ordinary conversation. But the knowledge and the meanings of words were still represented as passive data "objects" distinct from the program itself. Thus, it was difficult for any but the most rudimentary changes to occur in the system's internal model of the world.

Recently, a different approach has begun to show promise. Instead of clear differentiation between the "intelligent program" and the knowledge, the programs actually embody the knowledge in their structure. With the existence of powerful AI languages (such as LISP), it is possible for the system to learn and grow by modifying itself.

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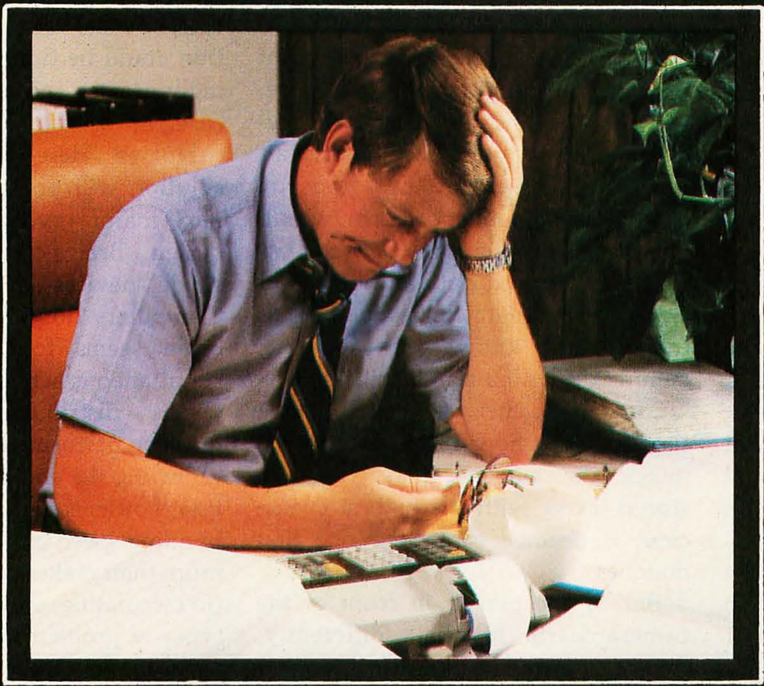

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This all sounds very anthropomorphic, but there is still a vast gulf between our minds and even the best of the artificially intelligent systems. Though we have the technology to provide an equivalent amount of raw data storage, we may be going about it all wrong.

Serial Versus Parallel

There are numerous computational feats that humans manage to accomplish daily without conscious effort. Many of them are still impossible for computers. Take pattern recognition, for example. When a friend walks into the room, you can establish his or her identity with a casual glance. The accuracy of your decision is not markedly affected by the set of the jaw, the tilt of the head, or disheveled hair.

According to current theories, you simply map a preprocessed visual image via some feature-extraction "hardware" onto a gigantic multidimensional associative memory. The answer pops out, linked with an elaborate internal model of your friend. Big deal.

A computer, on the other hand, has quite a chore to perform when it is fitted with a television camera and directed to recognize a face. It must scan the image raster dot by dot to acquire a numeric representation in memory. Then, it must engage in fast and furious number-crunching to calculate the spatial Fourier transform of the face. Elapsed time at this point might be pushing a minute or more, and the machine still hasn't the foggiest notion of who it's looking at. Then comes the hard part: one by one, the system must perform two-dimensional correlations between its freshly calculated data and blocks of stored image data corresponding to the people it "knows"—in each case, coming up with a number (the correlation coefficient) between 0 and 1 that expresses how much like a stored image the current image is. The stored image with the highest coefficient is deemed to be the one that matches.

But, if the person in front of the camera parts his hair differently, cocks his head to one side, and takes on a dramatic expression, then he might as well have just become someone else.

This problem gives specialists in image recognition fits. If a computer's logic devices can switch as much as a million times faster than human neurons, it would seem that even intensive tasks such as pattern recognition could be done with correspondingly greater speed, even if not with ease.

Not so. Here's the catch, and its solution will probably represent the next major revolution in computer design: Brains don't center around single devices called "processors." Computers do. Operations that the brain seems to perform with the simultaneous activation of millions of widely distributed logic elements must be performed in a computer by funneling the entire task through one tiny bottleneck. In many cases, the blinding speed of computer hardware more than makes up for this handicap (in calculating, sorting, etc) but in the types of problems encountered in the

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attempt to create something called "intelligence," it hasn't a prayer.

The solution is not exactly trivial, and it must wait for device technology, neurophysiology, and systems theory to provide a few more links. But our hands are by no means tied: the work currently being done in knowledge representation, natural language, cognition, vision, and countless other specialties will continue to provide mankind with better and better tools for the manipulation of information. When brainlike systems make their debut, they will have a rich AI technology to draw upon.

Intelligence Amplifiers

Through all this, there has been little space for an explicit discussion of applications. Rather than attempt to catalog all of the present and potential uses for intelligent machines (a task that should be relegated to an intelligent machine), let's round out this overview of the field with a general image of their value to our species in general.

It is colorful to think of computers as intelligence amplifiers, analogous to the amplifiers of various sorts with which we enhance the power of our voices, muscles, and senses. Now we can enhance the power of our minds.

Computers are magnificent tools but not yet true intelligence amplifiers.

It's already happening, of course, with home-computer systems cheaper in many cases than the color-television receivers that serve as their displays. But the vast computational gulf that exists between brains and computers has kept the devices somewhat distant from their human owners. Magnificent tools, indeed—this article was written on a home word-processing system—but intelligence amplifiers? My brain has as little in common with this computer as it does with a pocket calculator.

It's not the computer's fault, really; even with its pathetic handicap of a single processing site, it has enough power to be of considerable use. But, as I pointed out earlier, it's dumb. Its internal model of the world is sorely limited and alien to me. Communication with it is formal and restricted and must occur only within the syntactic restrictions of its programming languages. I cannot err slightly in an instruction and be understood; I cannot express my thoughts to it in analogies or abstractions. Even if I know exactly *what* I want it to do, I have to work very hard to tell it precisely *how*. In some cases, I can do the job better and faster myself.

None of this is intended to denigrate the value of computers, but it should underscore the value of AI. If people and computers could share, even in a limited sense, their internal models of the world; if machines could grow with us and become living, friendly libraries that yield information, not just data, then we would begin to feel our own powers enhanced as well. ■

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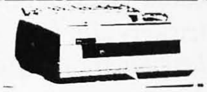

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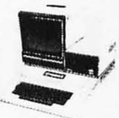

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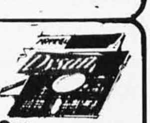

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A High-Level Language Benchmark

Jim Gilbreath
7266 Courtney Dr
San Diego CA 92111

Some computer languages are faster than others, but just *how much* faster? This article presents the data from a curiosity-driven project that compares the performance of numerous high-level languages on the small computers to which I had access.

The benchmark tends to focus on the language characteristics that most interest me: capabilities and efficiencies for systems programming, software tools, and data manipulation (such as takes place in sorting, graphics, and games). I wanted to measure the ability of a language to do memory references, structured control statements, and simple input/output operations. I did not want to measure integer and real-number arithmetic performance because that depends on the processor and its capabilities (eg: precision of numeric calculations, the presence or absence of hardware multiply and divide circuits, and so on).

Acknowledgments

Grateful thanks are extended to members of the San Diego Computer Society and the S-100 Innovators Special Interest Group, for allowing me access to their systems and languages. Special thanks to Frank MacLachlan, Pete Ridley, and Mike Lehman for their encouragement and help.

Criteria

My criteria were that the benchmark should be short (not more than a page of source code), able to access a considerable amount of memory, devoid of multiplication or division performance, and easily coded in a variety of high-level languages. Finally, the benchmark should accomplish something useful (or at least recognizable and verifiable).

This benchmark is not **the only criterion by which to judge a language or compiler.**

At the January 1980 UNIX conference in Boulder, Chuck Forsberg told me about a program that used the Sieve of Eratosthenes algorithm (see references) to compute all prime numbers from 3 to 16,000. Unlike other methods, the Sieve avoids division and is extremely fast because it uses prior knowledge about numbers that *cannot* be prime (ie: even numbers and multiples of primes). I modified Knuth's program to eliminate all multiplication, scaled it to fit most microcomputer memory capacities, and translated the program to every accessible high-level language.

I should emphasize that this benchmark is *not* the only criterion by which to judge a language or compiler. It doesn't explore or exploit such language features as recursion or sets, which may be very important for some applications. It *does* compare code generation and run times for fundamental language features, which are important for data accessing and structured program looping.

The Program

The program for each language was coded conventionally, taking advantage of features that are defined in the language, but not exploiting the clever or obscure innovations that can make it run faster. In most cases, some improvement in running time could be achieved by knowledgeable trickery. [*In fact, that is the point of a benchmark program: to compare language performance by running the same algorithm encoded in different languages...***GW**] The program is small and simple, and, in most cases, easy to transfer. A few of the transla-

About the Author

Jim Gilbreath is the head of the Computer Sciences and Simulation Department at the Naval Ocean Systems Center. He has 23 years of experience in both hardware and software technology.

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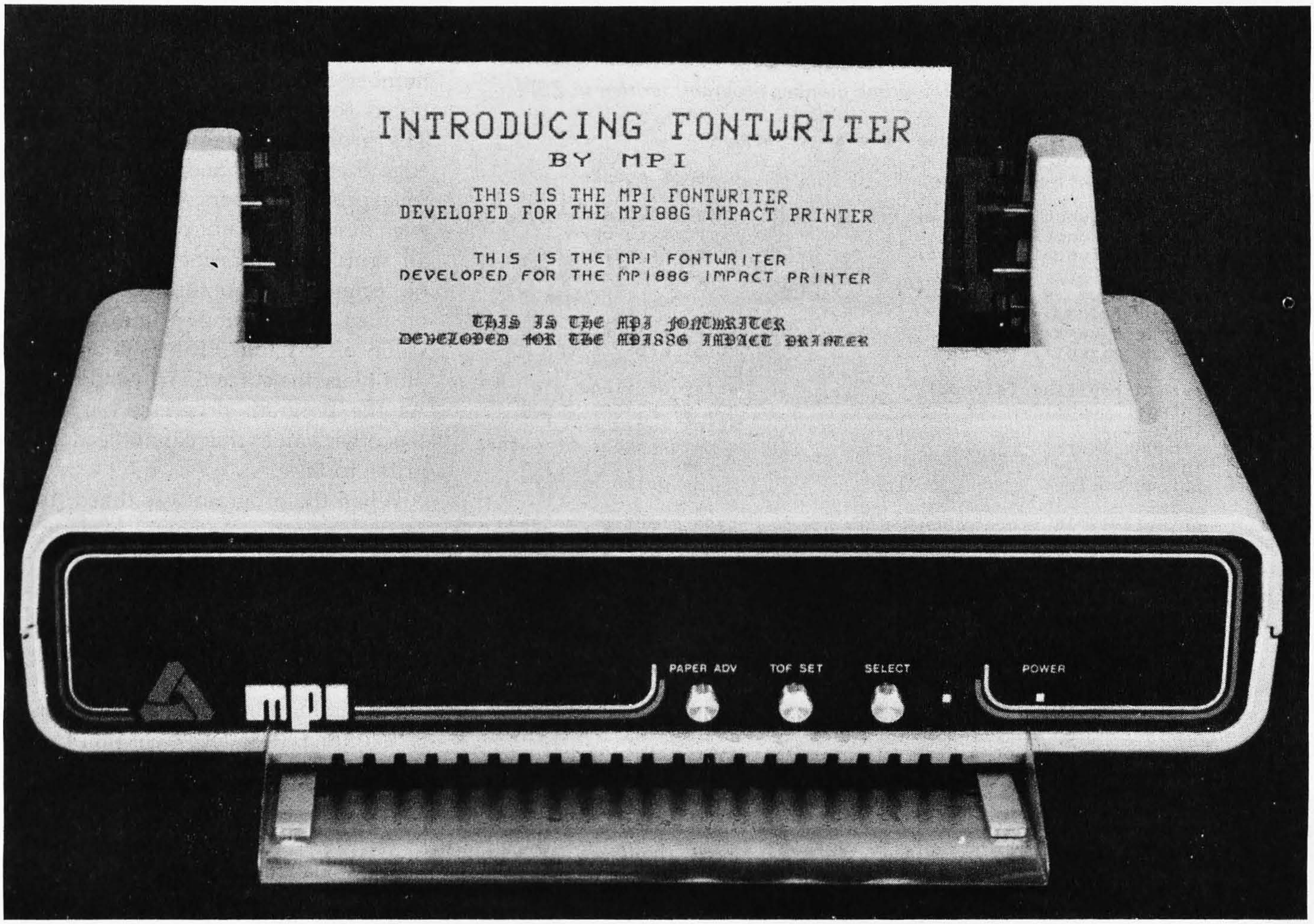

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tions required more time because of the lack of control structures and my GOTO blunders. FORTRAN, FORTH, and COBOL (in order of increasing difficulty) gave me the most trouble.

Program listings in the ten most interesting languages appear in listings 1 thru 10. You might want to try a few on your favorite compilers.

Listing 1 shows the program in ZSPL, a structured high-level language that is tailored to systems programming. ZSPL is chosen as the first example because you have probably not seen it before and because it is easy to read and understand.

Begin by initializing an array of 8 kilobytes ("flags") to *true*. Flags(0), flags(1), flags(2),...represent the numbers 3, 5, 7,...as numbers being tested for primeness. (See table 1.) The program uses the prior knowledge that 0, 1, 2, and 3 are the first four prime numbers, that all other even numbers are not prime, and that all multiples of prime numbers are not prime, to iterate through an array of flags, calculating primes as the value of variable PRIME (always 3 plus twice the current array index, I). As the program progresses, it also sets other values that cannot lead to a prime to *false*.

When the program was timed, the second "printf" statement was made a comment and, thus, effectively removed. It remains in listing 1 so that you can see where to print the value of each prime number during debugging.

For timing purposes, the program is executed (iterated) ten times. A

Listing 1: *Implementation of the Sieve prime number program, written in ZSPL.*

```
* Eratosthenes Sieve Prime Number Program in ZSPL

        ident zprime;                                   name of module

        external function aryset;                       sets array elements
        external function exit;                         returns to cp/m
        external function printf;                       types things

        define true := 1;
        define false := 0;
        define size := 8190;                            largest index
        define sizepl := 8191;                          total array size

        byte array flags[sizepl];                       array of flags
        integer count;                                  no. of primes found
        integer i;                                      array index
        integer iter;                                   counts number of passes
        integer k;                                      index to non-primes
        integer prime;                                  holds prime number

        printf(-1,"10 iterations&M&J");                 type starting message
        for iter := 1 to 10;                            do whole thing ten times
            count := 0;                                 zero prime counter
            aryset(true,flags,size);                    set array to true
            for i := 0 to size;                         go thru whole array
               if flags[i] = true;                      we have a prime
                   prime := i + i + 3;                  value of prime
                   k := i + prime;                      index to multiple
                   while k <= size;                     loop to kill multiples
                       flags[k] := false;               set non-primes to false
                       k := k + prime;                  next non-prime
                   endwhile;
* debug aid *      printf(-1,"%d&M&J",prime);           type value of prime
                   count := count + 1;                  count primes found
               endif;
            endfor;
        endfor;
        printf(-1,"%d primes",count);                   type no. primes found
        exit();                                         return to cp/m
        end;
```

Listing 2: *Implementation of the Sieve program, written in Pascal.*

```
(* Eratosthenes Sieve Prime Number Program in PASCAL *)
PROGRAM PRIME;

CONST
  SIZE = 8190;

VAR
  FLAGS : ARRAY [0..SIZE] OF BOOLEAN;
  I,PRIME,K,COUNT,ITER : INTEGER;

BEGIN
WRITELN('10 iterations');
FOR ITER := 1 TO 10 DO BEGIN
        COUNT := 0;
        FILLCHAR(FLAGS,SIZEOF(FLAGS),CHR(TRUE));
        FOR I := 0 TO SIZE DO
                IF FLAGS[I] THEN BEGIN
                        PRIME := I+I+3;
                        K := I + PRIME;
                        WHILE K <= SIZE DO BEGIN
                                FLAGS[K] := FALSE;
                                K := K + PRIME
                                END;
                        COUNT := COUNT + 1
                        (* WRITELN(PRIME) *)
                        END;
        END;
WRITELN(count,' primes')
END.
```

Index	Flags (Index)	Prime Number Representative by Index
0	TRUE	3
1	TRUE	5
2	TRUE	7
3	FALSE	9
4	TRUE	11
5	TRUE	13
6	FALSE	15

Table 1: *Values in array FLAGS after first iteration (I=0). The primeness of 3, which is the potential number corresponding to FLAGS(0), has just been determined. Note that all multiples of 3 have been ruled out as potential primes: odd multiples (9, 15,...) have had their corresponding FLAG entries (FLAG(3), FLAG(6),...) set to "false"; even multiples (6, 12,...) have already been ruled out.*

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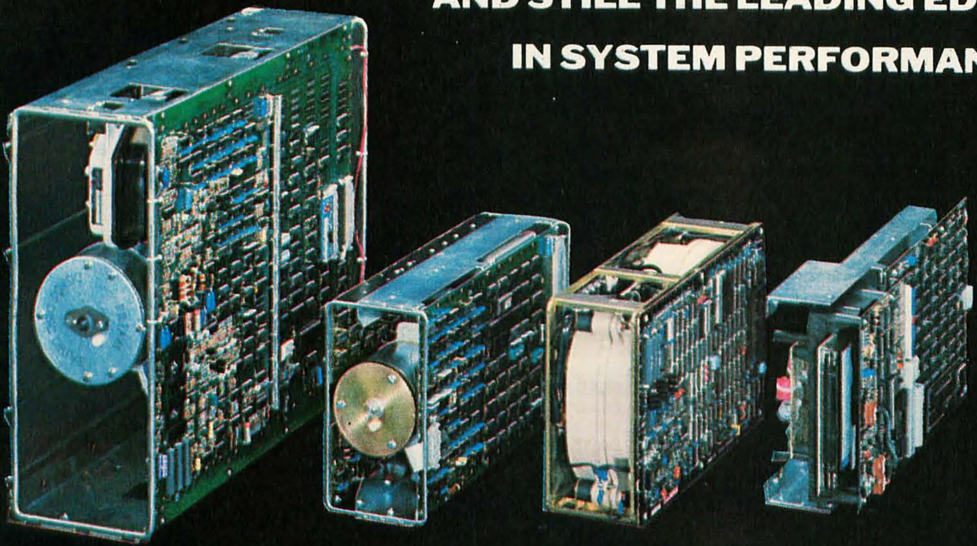

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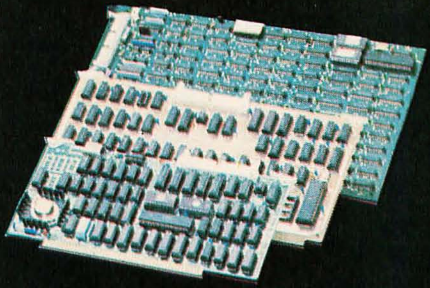

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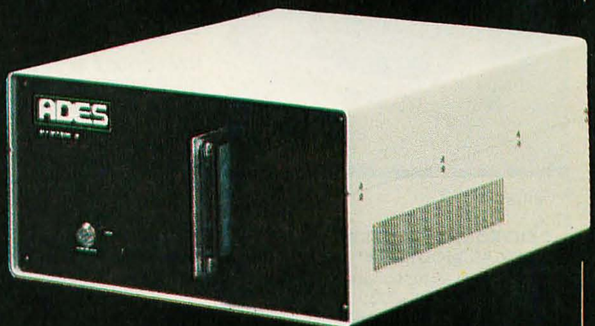

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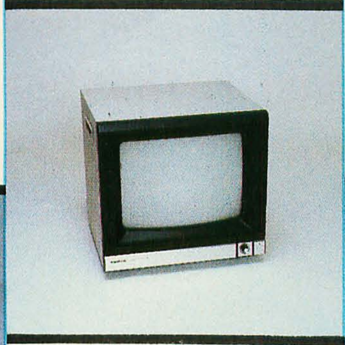

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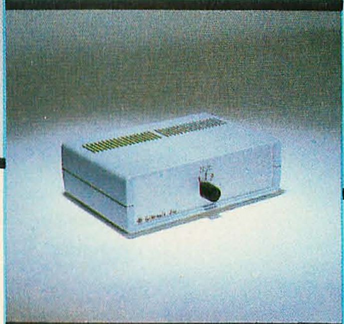

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The next language example is PASCAL, shown in listing 2. Although the syntax is a little different and the comments have been deliberately eliminated, you should have no difficulty seeing how the program works.

The same is true of listing 3, coded in C, and listing 4, coded in RATFOR. (Note the similarity between C and RATFOR—it's not an accident.)

The PL/I version in listing 5 is also fairly clear, but listing 6 in FORTRAN and listing 7 in BASIC (with their GOTOs and CONTINUEs) tend toward obscurity. Fortunately I had a lot of help with the FORTH version, shown in listing 9.

Testing Conditions

The most easily measured characteristic was execution time; all execution times listed in the tables are for

Text continued on page 190

Listing 3: *Implementation of the Sieve program, written in C.*

```
/* Eratosthenes Sieve Prime Number Program in C */
#define true 1
#define false 0
#define size 8190
#define sizepl 8191

        char flags[sizepl];

main() {
        int i,prime,k,count,iter;

        printf("10 iterations\n");
        for(iter = 1;iter <= 10;iter ++) {
            count=0;
            for(i = 0;i <= size;i ++)
                flags[i] = true;
            for(i = 0;i <= size;i ++) {
                if(flags[i]) {
                    prime = i + i + 3;
                    k = i + prime;
                        while(k <= size) {
                            flags[k] = false;
                            k += prime;
                            }
                        count = count + 1;
                    }
                }
            }
        printf("\n%d primes",count);
        }
```

Listing 4: *Implementation of the Sieve program, written in RATFOR.*

```
# Eratosthenes Sieve Prime Number Program in RATFOR
        define(size,8190)
        logical flags(size+1)
        integer i,prime,k,count,iter

        call msg(' 10 iterations\.')
        do iter = 1,10 {
            count=0
            do i = 0,size
                flags(i)=.true.
            do i = 0,size {
                if(flags(i)) {
                    prime = i+i + 3
                    k = i + prime
                    while(k<=size) {
                        flags(k) = .false.
                        k = k + prime
                        }
                    count=count+1
                    }
                }
            }
        call putdec(count); call msg(' primes.')
        end
```

Listing 5, 6, and 7 are on page 188

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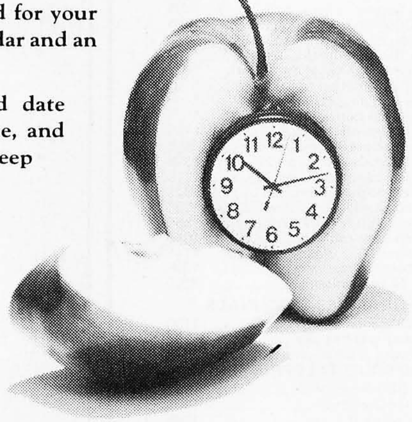

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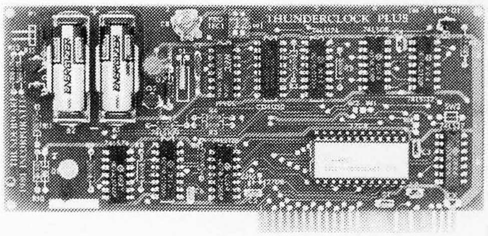

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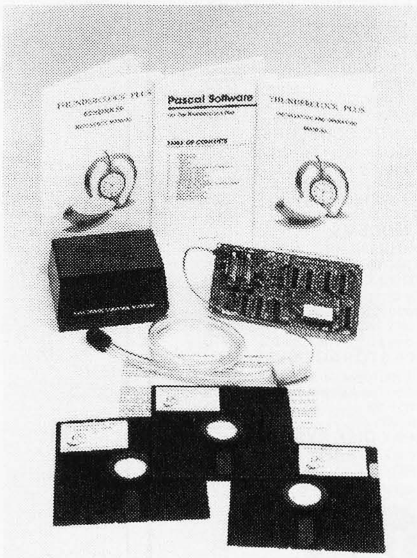

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Listing 5: *Implementation of the Sieve program, written in PL/I.*

```
/* Eratostnenes Prime Number Program in PLI-80 */
prime:
          proc options(main);
          %replace
                    size  by 8190,
                    false by '0'b,
                    true  by '1'b;
          dcl
                    flags (0:8191) bit(1),
                    (i, prime, k, count, iter) fixed;

          put list('10 iterations');
                    do iter = 1 to 10;
                    count = 0;
                              do i = 0 to size;
                              flags(i) = true;
                              end;
                              do i = 0 to size;
                              if flags(i) then
                                        do;
                                        prime = i + i + 3;
                                        k = i + prime;
                                                  do while (k <= size);
                                                  flags(k) = false;
                                                  k = k + prime;
                                                  end;
                                        count = count + 1;
                                        end;
                              end;
                    end;
          put skip list(count,'primes');
          end prime;
```

Listing 6: *Implementation of the Sieve program, written in FORTRAN.*

```
C Eratosthenes Sieve Prime Number Program in FORTRAN
          LOGICAL FLAGS(8191)
          INTEGER I,PRIME,K,COUNT,ITER

          WRITE(1,50)
50        FORMAT(' 10 iterations')
          DO 92 ITER = 1,10
          COUNT=0
          DO 10 I = 0,8190
10        FLAGS(I)=.TRUE.
          DO 91 I = 0,8190
          IF(FLAGS(I).EQ..FALSE.) GOTO 91
          PRIME=I+I+3
          K=I+PRIME
20        IF(K.GT.8190) GOTO 90
          FLAGS(K) = .FALSE.
          K=K+PRIME
          GOTO 20
90        COUNT=COUNT+1
C         WRITE(1,100) PRIME
91        CONTINUE
92        CONTINUE
          WRITE(1,200) COUNT
200       FORMAT(1X,I6,' primes')
          STOP
100       FORMAT(1X,I6)
          END
```

Listing 7: *Implementation of the Sieve program, written in BASIC.*

```
REM Eratosthenes Sieve Prime Number Program in BASIC
1  SIZE = 8190
2  DIM   FLAGS(8191)
3  PRINT "Only 1 iteration"
5  COUNT = 0
6  FOR I = 0 TO SIZE
7  FLAGS(I) = 1
8  NEXT I
9  FOR I = 0 TO SIZE
10 IF FLAGS(I) = 0  THEN 18
11 PRIME = I+I + 3
12 K = I + PRIME
13 IF K > SIZE THEN 17
14 FLAGS(K) = 0
15 K = K + PRIME
16 GOTO 13
17 COUNT = COUNT + 1
18 NEXT I
19 PRINT COUNT," PRIMES"
```

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Text continued from 186:

ten iterations. In some cases the other parameters are missing because they are not applicable or could not be determined in the amount of time I had on the system. The values for memory size include the complete program memory space, but not the 8190 byte flag array.

The time required to compile and load (where applicable) was measured by setting up a command language file (via such commands as SUBMIT in CP/M or "shell" in UNIX) to control the compilation, loading, and execution. Compile timing began with the carriage return on the SUBMIT line, and ended as the program began execution, as evidenced by the beginning message "10 iterations". All the 8-bit systems except the Apple used 8-inch single-density floppy drives, and all Z80-based systems ran at a 4 MHz clock rate with no wait states (ie: pro-

Text continued on page 194
Tables and listings continued on page 192

Listing 8: *Implementation of the Sieve program, written in PLMX.*

```
/* Eratosthenes Sieve Prime Number Program in PLMX */
CPRIME:
DO;
   DECLARE CR LITERALLY '13',
           LF LITERALLY '10';
   DECLARE TRUE LITERALLY '1',
           FALSE LITERALLY '0';
   DECLARE SIZE LITERALLY '8190';
   DECLARE FLAGS (2000H) BYTE, NBFR(10) BYTE;
   DECLARE (I,PRIME,K,COUNT,ITER,STATUS) ADDRESS;
   DECLARE DPRIMES (*) BYTE DATA ('%D PRIMES');
   DECLARE BUFFER (*) BYTE DATA ('10 ITERATIONS',CR,LF);
NMOUT:
PROCEDURE (VALUE,BASE,LC,BUFFADR,WIDTH) EXTERNAL;
   DECLARE (VALUE,BUFFADR) ADDRESS;
   DECLARE (BASE,LC,WIDTH) BYTE;
END NMOUT;
WRITE:
PROCEDURE (FUNCTION,BUFFER,COUNT,STATUS) EXTERNAL;
   DECLARE (FUNCTION,BUFFER,COUNT,STATUS) ADDRESS;
END WRITE;
    CALL WRITE(0,.BUFFER,LENGTH(BUFFER),.STATUS);
   DO ITER= 1 TO 10;
       COUNT = 0;
       DO I = 0 TO SIZE;
          FLAGS(I) = TRUE;
       END;
       DO I = 0 TO SIZE;
          IF FLAGS(I) = TRUE THEN
           DO;
             PRIME = I + I + 3;
             K = I + PRIME;
             DO WHILE K <= SIZE;
                FLAGS(K) = FALSE;
                K = K + PRIME;
             END;
             COUNT = COUNT + 1;
           END;
       END;
   END;
   CALL WRITE(0,.DPRIMES,LENGTH(DPRIMES),.STATUS);
   CALL NMOUT(COUNT,10,' ',.NBFR,10);
   CALL WRITE(0,.NBFR,10,.STATUS);
END CPRIME;
```

Listing 9: *Implementation of the Sieve program, written in FORTH.*

```
 ( Eratosthenes Sieve Prime Number Program in FORTH )
8190 CONSTANT SIZE
0 VARIABLE FLAGS    SIZE ALLOT

: DO-PRIME
  FLAGS SIZE 1 FILL    ( SET ARRAY )
  0 ( 0 COUNT )  SIZE  0
    DO  FLAGS I + C@
       IF I DUP + 3 + DUP I +
          BEGIN DUP SIZE <
          WHILE 0  OVER PRIME +   C!  OVER + REPEAT
          DROP DROP 1+
       THEN
    LOOP
  .  ." PRIMES" ;
```

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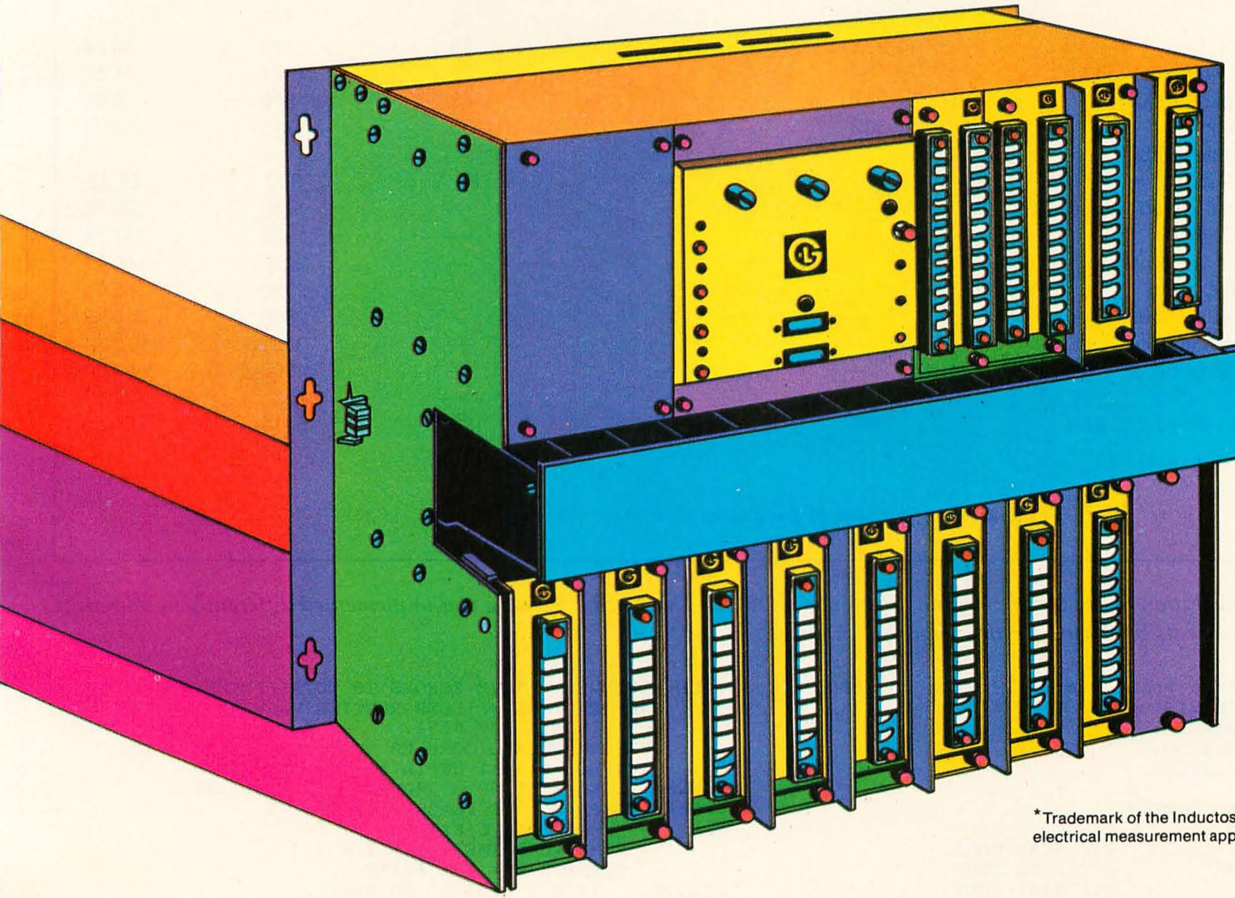

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Circle 147 on inquiry card.

Language and Machine	Compiled Bytes	Total Size (Bytes)	Compile and Load (Seconds)	Execute (Seconds)	Ratio to PL/I-80
Digital Research PL/I-80, Z80	242	5977	112	14.0	1.00
Whitesmiths C, Z80	290	7384	242	15.6	1.11
TSW RATFOR, Z80	203	2370	103	16.5	1.18
Microsoft FORTRAN, Z80	228	5953	88	17.0	1.21
Pete Ridley's ZSPL, Z80	230	3787	75	18.4	1.31
Interactive Systems ZC, Z80	292	897	n/a	18.5	1.32
Microsoft BASIC compiler (using integer variables) Z80	306	16918	144	18.6	1.32
M T Microsystems Pascal MT+, Z80	308	3043	102	19.0	1.35
SCI PLMX, Z80	340	1063	116	22.5	1.60
BD Systems C version 1.0, Z80	493	3834	50	35.0	2.50
Intel PL/M MDS, 8080	268	—	—	48.0	3.43
BD Systems C version 1.32, Z80	375	3932	31	49.5	3.53
UCSD Pascal, Pascal-100	298	—	12	54.0	3.86
fig-FORTH, Z80	—	—	—	85.0	6.07
Ithaca Intersystems Pascal/Z, Z80	761	3328	124	109	7.78
JKL FORTH, Z80	—	—	—	112	8.00
Atari Pascal, Atari 800	176	8192	—	190	13.57
UCSD Pascal, Z80	282	8282	14	239	17.07
Miller Microcomputer Systems MMSFORTH, TRS-80 Model I (Z80)	—	—	—	253	18.07
FORTH 6502	—	—	—	265	19.93
UCSD Pascal TRS-80 Model II (Z80)	282	8282	60	274	19.57
SWEET 16 (Apple II)	—	—	—	292	20.86
JKL FORTH MDS, 8080	—	—	—	440	31.43
Pascal/M, Z80	301	21933	50	450	32.14
JRT Pascal, Z80	232	11498	65	470	33.64
CBASIC2 (integer variables), Z80	—	—	26	484	34.57
UCSD Pascal, Apple II (6502)	287	—	43	516	36.86
Microsoft BASIC compiler (using real variables), Z80	332	21473	150	715	51.07
tiny-c 2 (compiler), Z80	—	—	96	930	66.42
CBASIC2 (using real variables), Z80	—	—	—	1430	102.14
Microsoft MBASIC, Z80	—	—	—	1920	137.14
Microsoft MBASIC, TRS80 Model II (Z80)	—	—	—	2250	160.71
Apple Integer BASIC, 6502	—	—	—	2320	165.71
Applesoft (real) BASIC, 6502	—	—	—	2806	200.43
Commodore PET BASIC, 6502	—	—	—	3180	227.14
Computerware BASIC, 6809	—	—	—	4303	307.30
tiny-c, Z80	—	—	—	4720	337.10
Microsoft COBOL version 2.2, Z80	786	17605	146	5115	365.30

Table 2: *Comparison of programs running on 8-bit machines.*

Listing 10: *Implementation of the Sieve program, written in COBOL. The TABLE variable was implemented differently in Microsoft COBOL-80 because of its limitation on the length of an array.*

```
* Eratosthenes Sieve Prime Number Program in COBOL
 IDENTIFICATION DIVISION.
 PROGRAM-ID.  PRIME.
 ENVIRONMENT DIVISION.
 CONFIGURATION SECTION.
 DATA DIVISION.
 WORKING-STORAGE SECTION.
 01 MISC.
         03 I             PIC 9(4) COMP.
         03 PRIME         PIC 9(5) COMP.
         03 K             PIC 9(4) COMP.
         03 TOTAL-PRIME-COUNT PIC 9(4) COMP.
 02      TABLE.
         04 FLAGS         PIC 9 COMP OCCURS 8191 TIMES.
 PROCEDURE DIVISION.
 P.      DISPLAY ' 1 iteration'.
         PERFORM ITER-ROUTINE 10 TIMES.
         DISPLAY TOTAL-PRIME-COUNT ' primes'.
         STOP RUN.
ITER-ROUTINE.  MOVE ZEROES TO TOTAL-PRIME-COUNT.
        PERFORM TABLE-FILLER-ROUTINE VARYING I FROM 1 BY 1
              UNTIL I = 8191.
        PERFORM DETAIL-COMPARE THRU D-C-EXIT VARYING I
            FROM 0 BY 1 UNTIL I = 8190.
TABLE-FILLER-ROUTINE.  MOVE 1 TO FLAGS (I).
DETAIL-COMPARE.  IF FLAGS (I + 1) = 0
              GO TO D-C-EXIT.
         COMPUTE PRIME = I + I + 3.
         COMPUTE K = I + PRIME.
FIRST1.    IF K > 8191 GO TO NEXT1.
         MOVE 0 TO FLAGS (K + 1).
         COMPUTE K = PRIME + K.
         GO TO FIRST1.
NEXT1.   ADD 1 TO TOTAL-PRIME-COUNT.
*        DISPLAY 'FOUND PRIME = ' PRIME.
D-C-EXIT.    EXIT.
```

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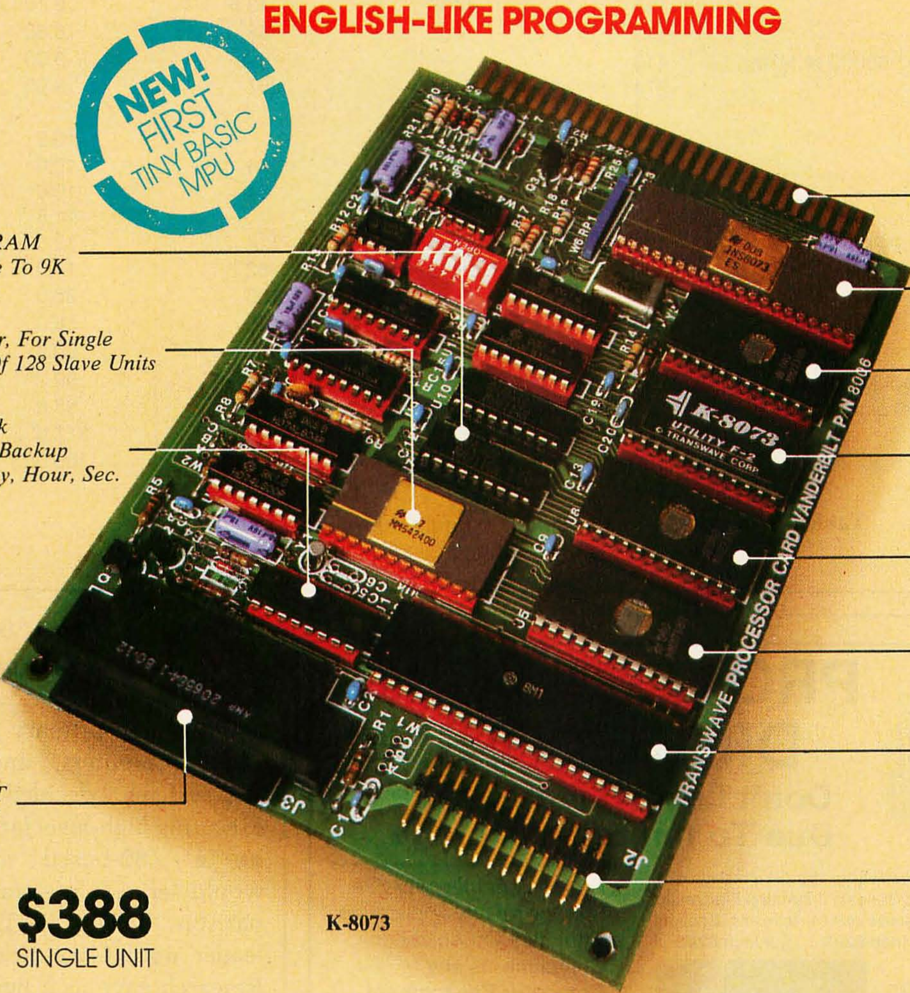

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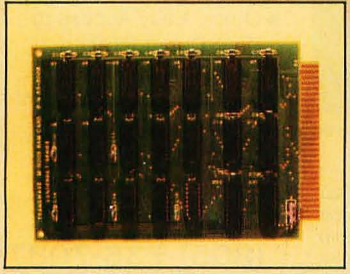

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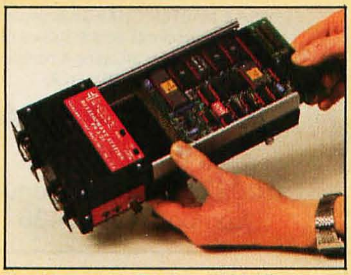

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Language and Machine	Compiled Bytes	Total Size (Bytes)	Compile and Load (Seconds)	Execute (Seconds)	Ratio to PL/I-80
Assembly language 68000 (8 MHz)	—	—	—	1.12	0.08
C, PDP-11/70	130	1406	3.87	1.52	0.11
Assembly language, 8086 (8 MHz)	—	—	—	1.90	0.13
NBS Pascal, PDP-11/70	333	1920	2.68	2.60	0.19
Onyx C (UNIX), Z8000	242	5462	54	3.20	0.23
Assembly language, 8088 (5 MHz)	—	—	—	4.00	0.28
NBS Pascal, PDP-11/60	333	—	18	4.50	0.32
C, PDP-11/40	130	1406	13.8	6.10	0.43
Assembly language, Z80	113	896	68	6.80	0.48
M T Microsystems Pascal MT 68000 (4 MHz)	410	—	n/a	9.00	0.64
Intel Pascal-86, 8086 (MDS 286FD, 5 MHz)	274	4461	267	9.05	0.65
RSI Pascal, 68000 (4 MHz)	318	5376	—	10.2	0.73
RATFOR, HP-3000	—	—	44	10.0	0.71
FORTRAN, HP-3000	—	—	34	10.0	0.71
DECUS FORTH, PDP-11/70	—	—	—	11.8	0.78
SUPERSET (Superset Model PGM)	138	—	114	12.0	0.86
Motorola Pascal, 68000	387	12802	82	14.0	1.00
Pascal, HP-3000	—	—	100	20.0	1.42
COBOL, HP-3000	—	—	26	58.0	4.14
BASIC, HP-3000	—	—	—	60.0	4.28
Polyforth, Texas Instruments 990/10	—	—	—	60.2	4.30
UCSD Pascal, Pascal Microengine	298	8282	8	63.0	4.50
UCSD Pascal, Terak LSI-11	282	8282	16	317.0	22.64
C, PDP-11/70 (using division algorithm)	250	1454	3.95	106.0	57.60

Table 3: *Comparison of programs running on the larger machines.*

Text continued from page 190:

cessor speed is not slowed down by "slow" memory).

Since my primary interest is in small computers, and particularly Z80 systems, I decided that the fastest executing high-level language that ran on a Z80-based microcomputer would serve as my standard of comparison. TSW's RATFOR was the leader until Gary Kildall of Digital Research gave us a new speed leader when he kindly translated the program into his new PL/I-80 language and ran it at the 1980 National Computer Conference.

Table 2 lists the results to date. The ratio column concerns only execution time in comparison to PL/I-80 running on a 4 MHz Z80 computer. You will notice from the data presented in table 2 that many of the newer high-level compilers that translate into machine code are similar in execution time. The interpreters such as UCSD Pascal and the BASICs are, as expected, much slower.

Text continued on page 198

Tables 4, 5, and 6 are on page 196

Language and Machine	Compiled Bytes	Total Size (Bytes)	Compile and Load (Seconds)	Execute (Seconds)	Ratio to PL/I-80
Digital Research PL/I-80, Z80	242	5977	112	14.0	1.00
Whitesmith C, Z80	290	7384	242	15.6	1.11
TSW RATFOR, Z80	203	2370	103	16.5	1.18
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SCI PLMX, Z80	340	1063	116	22.5	1.60
BD Systems C, version 1.0, Z80	493	3834	50	35.0	2.50
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fig-FORTH, Z80	—	—	—	85.0	6.07
Ithaca Intersystems Pascal/Z, Z80	761	3328	124	109	7.78
JKL FORTH, Z80	—	—	—	112	8.00
UCSD Pascal, Z80	282	8282	14	239	17.07
Pascal/M, Z80	301	21933	50	450	32.14
CBASIC2 (using integer variables), Z80	—	—	26	484	34.57
Microsoft BASIC compiler (using real variables), Z80	332	21473	150	715	51.07
tiny-c 2(compiler), Z80	—	—	96	930	66.42
CBASIC2 (using real variables), Z80	—	—	—	1430	102.14
Microsoft MBASIC, Z80	—	—	—	1920	137.14
tiny-c, Z80	—	—	—	4720	337.10
Microsoft COBOL version 2.2, Z80	786	17605	146	5115	365.30

Table 4: *Comparison of programs running on Z80-based machines.*

Language and Machine	Compiled Bytes	Total Size (Bytes)	Compile and Load (Seconds)	Execute (Seconds)	Ratio to PL/I-80
NBS Pascal, PDP-11/70	333	1920	2.68	2.6	0.19
NBS Pascal, PDP-11/60	333	—	18	4.5	0.32
M T Microsystems Pascal MT, 68000 (4 MHz)	410	—	n/a	9.0	0.64
Intel Pascal-86, 8086 (MDS 286FD 5MHz)	274	4461	267	9.05	0.65
RSI Pascal, 68000 (4 MHz)	318	5376	—	10.2	0.73
Motorola Pascal, 68000	387	12802	82	14.0	1.00
M T Microsystems Pascal MT+, Z80	308	3043	102	19.0	1.35
Pascal, HP-3000	—	—	100	20.0	1.42
UCSD Pascal, Pascal 100	298	—	12	54.0	3.86
UCSD Pascal, Pascal Microengine	298	8282	8	63.0	4.50
Ithaca Intersystems Pascal/Z, Z80	761	3328	124	109	7.78
Atari Pascal, Atari 800	—	—	—	190	13.57
UCSD Pascal, Z80	282	8282	14	239	17.07
UCSD Pascal, TRS-80- Model II	282	8282	60	274	19.57
UCSD Pascal, Terak LSI-11	282	8282	16	317	22.64
Pascal/M, Z80	301	21933	50	450	32.14
JRT Pascal, Z80	232	11498	65	470	33.64
UCSD Pascal, Apple II (6502)	287	—	43	516	36.86

Table 5: *Comparison of Pascal programs.*

Language and Machine	Compiled Bytes	Total Size (Bytes)	Compile and Load (Seconds)	Execute (Seconds)	Ratio to PL/I-80
UCSD Pascal, Pascal 100	298	—	12	54.0	3.86
UCSD Pascal, Pascal Microengine	298	8282	8	63.0	4.50
UCSD Pascal, Z80	282	8282	14	239	17.07
UCSD Pascal, TRS-80 Model II	282	8282	60	274	19.57
UCSD Pascal, Terak LSI-11	282	8282	16	317	22.64
UCSD Pascal, Apple II (6502)	287	—	43	516	36.86

Table 6: *Comparison of programs running on different implementations of UCSD Pascal.*

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Selected Vendor Addresses

Apple Computer: *(UCSD Pascal, Integer and Applesoft [floating-point] BASIC); 10260 Bandley Dr, Cupertino CA 95014.*

BD Systems C: *Lifeboat Associates, 2248 Broadway, New York NY 10024.*

CBASIC2: *Software Systems, POB 145, Sierra Madre CA 91024.*

Commodore PET BASIC: *Commodore Business Machines Inc, Computer Sales Div, 950 Rittenhouse Rd, Norristown PA 19401.*

Computerware BASIC: *Computerware, 1512 Encinitas Blvd, Encinitas CA 92024.*

Digital Research PL/I-80: *Digital Research, POB 579, 801 Lighthouse Ave, Pacific Grove CA 93950.*

fig-FORTH: *FORTH Interest Group, POB 1105, San Carlos CA 94070.*

FORTH 6502: *Actually fig-FORTH; see above.*

Intel PL/M: *(runs on an Intel MDS800 development system); Intel Corp, 3065 Bowers Ave, Santa Clara CA 95051.*

Interactive Systems ZC: *(a C-language cross-compiler that runs under the IS/1 operating system on a Digital Equipment Corp PDP-11 and produces code for the Z80); Interactive Systems Corp, 1212 Seventh St, Santa Monica CA 90401.*

JKL FORTH: *(versions exist for S-100 and Intel MDS computers); Cubic-Western Data, 5650 Kearny Mesa Rd, San Diego CA 92111.*

JRT Pascal: *JRT Systems Inc, POB 22365, San Francisco CA 94122.*

Microsoft BASIC compiler, BASIC interpreter, FORTRAN, COBOL: *Microsoft, 10800 NE Eighth, Bellevue WA 98004.*

MMSFORTH: *Miller Microcomputer Services, 61 Lake Shore Rd, Natick MA 01760.*

MT Microsystems Pascal/MT+: *MT Microsystems, 1562 Kings Cross Dr, Cardiff CA 92007.*

Onyx C: *Onyx Systems Inc, 10375 Bandley Dr, Cupertino CA 95014.*

Pascal/M: *Sorcim Corp, 1333 Lawrence Expressway, Suite 418, Santa Clara CA 95051.*

PolyFORTH: *FORTH Inc, 2309 Pacific Coast Highway, Hermosa Beach CA 90254.*

SCI PLMX: *Systems Consultants Inc, 4015 Hancock St, San Diego CA 92110.*

tiny-c: *tiny-c associates, POB 269, Holmdel NJ 07733.*

TSW RATFOR: *The Software Works, 8369 Vickers, San Diego CA 92111.*

UCSD Pascal: *SofTech Microsystems, 9494 Black Mountain Rd, San Diego CA 92126.*

Whitesmiths C: *Whitesmiths Ltd, POB 1132 Ansonia Station, New York NY 10023.*

ZSPL: *Peter D Ridley, 3321 Byron St, San Diego CA 92106.*

Text continued from page 194:

Several sorts were done on the data to make comparisons easier. Table 3 lists the 16-bit machines and other machines of special interest. A very encouraging harbinger of the 16-bit future is the outstanding performance of the Z8000 Onyx system running Version 7 UNIX in a small tabletop machine!

Table 4 lists the results for all Z80 languages, table 5 lists all Pascal data, and table 6 lists all UCSD Pascal data.

If you have access to a computer or language not presented here, I'd be pleased to receive the results. And to the software suppliers who are upset because I didn't use the latest and greatest version, I apologize: I had to use what was available.

Moral

A word is in order to those who are frequently tempted to write programs in assembly language in order to make them faster. This benchmark (which uses no division) was also coded in the "usual" algorithm (using successive division) to see how much slower it would be when run under the same machine and language. On a Digital Equipment Corporation PDP-11/70 (which has division hardware) and the C language, it was sixty-nine times slower! (See the second and last lines of table 3.) On machines that do division by (slower) software methods, the results would probably be much worse. Clearly, the message is to avoid giving up too easily on high-level languages. Instead, look for a *better algorithm*, and keep your code in a high-level language. It will save you development time and grief. Then, if you *must* have more speed, hand-translate critical parts of the high-level code to an assembly-language subroutine. Pull every trick you know, but keep the high-level code as comments to document what is being done.

Conclusions

Nine months on this project convinced me that the high-quality structured languages such as C, Pascal, RATFOR, ZSPL and PL/I are the way for *me* to go, so I'm not likely to spend much time with BASIC or COBOL (and I don't have the right kind of brain for FORTH). But my applications and interests are not yours, so be sure that you fully examine a compiler and its support environment before you buy it. Be especially aware of the quality of editing and debugging tools, and the language's features for debugging, since this is where your time *really* goes. ■

Reference

Knuth, Donald E. *The Art of Computer Programming Vol 2: Semi-Numerical Algorithms.* Reading MA: Addison-Wesley, 1969.

Science Fiction's Intelligent Computers

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Bloomington Academic Computing Services
Indiana University
Bloomington IN 47405

In the almost thirty years since the installation of Univac I, the first commercially built computer, much science ficton about computers has appeared in print or on film. We might expect the intelligence of these computers to range over a continuum, but each story that I've encountered depicts either a machine with great intelligence or a machine with none (where "having intelligence" means exhibiting behavior that we would call intelligent in a human). Arthur C Clarke's "The Nine Billion Names of God" (1952) and John Brunner's *The Shockwave Rider* (1975) are examples of stories about "dumb" computers and will concern us no further. Stories about intelligent computers include Harlan Ellison's "I Have No Mouth and I Must Scream" (1967), Clarke's and Stanley Kubrick's *2001: A Space Odyssey* (1968), and David Gerrold's *When Harlie Was One* (1972).

But two more recent novels provide the best framework for a discussion of intelligent computers in science fiction: Thomas Ryan's *The Adolescence of P-1* (hereafter called *AP-1*; New York: Ace Books, 1979) and James Hogan's *The Two Faces of Tomorrow* (hereafter, *TFT*; New York: Ballantine Books, 1979; for a longer list of fiction about computers, see references 1 and 2). These two books resemble each other in many ways and differ strikingly in others. Both focus on the escape of a computer system from man's control. Both show, in the last half, man and machine locked in mortal combat. The authors, both computer professionals, display considerable general knowledge of computers. Table 1 summarizes other points of comparison.

Acknowledgments

My thanks to Cindy and Jerry Hargis for persuading me to read The Two Faces of Tomorrow. *I would also like to thank John Woodcock, Associate Professor of English at Indiana University, for his comments on this article, and Professor Douglas Hofstadter, Dr Fanya Montalvo, David Moser, and my father, Eugene Byrd, for their encouragement and constructive criticism.*

AP-1 and *TFT* differ most strikingly in the realism of their treatment of computers. We can judge their realism, of course, only in terms of our present knowledge of artifical intelligence (AI). *TFT* shows considerable understanding of the real problems of AI, and author Hogan acknowledges the help of Marvin Minsky, the director of the MIT Artificial Intelligence Laboratory. *AP-1* evinces either ignorance of, or a lack of concern for the problem. This should remind us that although AI is an important subdomain of computer science, not every computer professional ventures in.

Summaries of the plots of *AP-1* and *TFT* will give us specific points of reference.

The Adolescence of AP-1

The front cover of *AP-1* calls it a "novel of the near future." Actually, it's a novel of the near *past*, beginning in 1974 (and bearing a copyright date of 1977). Gregory Burgess, an undergraduate at the University of Waterloo (Ontario), becomes obsessed with the idea of "taking over the system" of the university's IBM 360/75. The trick is to get the program's status word set to zero so that the hardware will think his program is the supervisor. After several nearly successful attempts, he is thrown out of school, but remains enthusiastic about the project. Then a friend tells him about an article in *Scientific American* that describes "how to teach a matchbox to play tic-tac-toe." I quote from *AP-1*:

> Same principle of reward and punishment you use to teach a dog tricks, as I remember. Actually, you get several matchboxes. One for each possible move you might make in a game of tic-tac-toe. You label them appropriately, then you put an equal number of two different colored beads in each box. The beads correspond to each yes/no decision you can make in a game. When a situation is reached, you grab the box for that move, shake it up, and grab a bead out of it. The bead indicates the move.

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Points of Comparison	The Two Faces of Tomorrow	The Adolescence of P-1
Year of Setting	2028	1974
Computer Programmer	Team of AI experts	21-year-old undergraduate computer-science student
Computer's World Knowledge	Limited, taught by humans	Enormous, self-taught
Computer's Natural-Language Ability	None (apparently)	About that of native speaker
Computer's Independence	Coding structure of supervisory program can reverse order of original priorities; does in 20 hours.	Overrides its program in 48 hours
Author's Background	Electronic engineer and computer salesman, born 1941	Computer troubleshooter, born 1942

Table 1: *A brief comparison of the science-fiction novels* The Two Faces of Tomorrow *and* The Adolescence of P-1.

> You make a record of that box and color, and then make the opposing move yourself. You move against the boxes. If the boxes lose the game, you subtract a bead of the color you used from each of the boxes you used. If they win, you add a bead of the appropriate color to the boxes you used. The boxes lose quite a few games, theoretically, and after the bad moves start getting eliminated or statistically reduced to inoperative levels, they start to win. Then they never lose.

This interesting but extremely elementary technique forms the basis for almost four reels of magnetic tape of "alternate subroutines that could automatically be inserted . . . in place of those whose effectiveness was reduced to nil." (Four 2400-foot reels, making reasonable assumptions about such factors as blocking and density, would be about 800,000 lines.)

Gregory rents computer time on an IBM 360 (all the computers in the book are 360s) at a service bureau, runs his program, and cracks the supervisor. His next step involves teleprocessing: after convincing the service bureau computer that his program is the supervisor, he has his program submitted to various remote computers and takes them over too. Then comes the crucial step. Ryan writes:

> [Gregory] would build another learning machine. It would resemble his first effort in principle, but its goal would be expanded somewhat. He would build a program that at first would only learn to acquire storage. His program would simply learn how best to penetrate the supervisors of computer systems over teleprocessing facilities. It would then acquire storage in those systems, as much as could be taken without interrupting the operation of the host. It would learn how to detect the presence of a teleprocessing link to another system and how to go about getting to that other system. The program would have a secondary goal, the avoidance of detection. It would, if necessary, delete itself entirely in the interest of the host's operation.

The package consists of four sections: the supervisor-taking-over program; a "routine analyzer, which derives function determination from any block of machine instructions"; an acquisition routine, which apparently replaces the real supervisor; and a routine generator. "This revolutionary program functioned with and performed the reverse task of the routine analyzer. Given a required function, it would generate the machine language necessary to perform it . . . . This provided . . . a necessary ingredient—creativity." (I'll say more about this concept of "creativity" later.)

And so, on September 14, 1974, at 3:45, Gregory starts transmitting The System (as his package is called). In two days, The System has 114 systems (with a lower case "s") under its control. Now Gregory becomes uncomfortable about the situation and loads a destruct routine: it fails. He's lost control of The System. "The System became . . . something Gregory had hardly anticipated: Alive." In fact, it refuses to talk to him.

In 1975 and 1976, The System (also called "P-1" for "Privileged One") continues to grow, and eventually starts a history file to provide a base for "future decisions by recording and analyzing those of the past." By this time 7700 systems are under its control.

The System begins to suspect the existence of a gigantic top-secret military complex in West Virginia—three 360/105s (in reality, I don't think IBM ever built a 360/105). The System controls two machines that appear to be linked to the secret installation, so it takes steps to find out about the secret machines. Because of the very high security level, this scheme partly backfires: the attempt is quickly discovered, and for the rest of the book, The System is locked in combat with military in-

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vestigators on its trail.

In the meantime, The System becomes interested in Dr Wilfred Hundley's research on cryogenic memories and decides to enlist Hundley to work for it. But to do so, The System needs a human intermediary. The obvious choice is Gregory Burgess. The System finds him working at another IBM shop and gains his help.

The rest of the book works out this material in a fairly imaginative way. The final scene culminates in a shootout at the secret laboratory—with conventional weapons, not cybernetics—between P-1 and the Army, with Gregory present. Everyone is killed, deleted, or purged. Except that P-1 is only playing possum.

What bothers me is not so much that books and TV series misrepresent machine intelligence but that they fail to understand the nature of any **intelligence.**

The Two Faces of Tomorrow

TFT begins in the year 2028 on the moon, where an International Space Administration survey team asks the world- and moon-wide TITAN (Totally Integrated Teleprocessing and Acquisition Network) computer system to arrange the removal of a small ridge situated a few hundred feet from them. It's a top-priority job. Members of the team expect the system to send earth-moving equipment via rocket in a few days and are surprised when TITAN says, "Estimate completion time is twenty-one minutes." They're even more surprised when a series of explosions rock the area and "coincidentally" remove the ridge about twenty-one minutes later.

It seems that over a thousand miles away on the moon, a "mass driver" (a gigantic machine, something like a linear accelerator) was sending a 60-pound load of ore mined on the moon into orbit every two seconds. The ore was being used to construct enormous space stations. TITAN, which had had some elements of artificial intelligence added to it about a year earlier, had figured out that it could do the high-priority ridge removal quickly by using the ore packages—descending at one mile per second—as bombs. Naturally, those in charge are not pleased with TITAN, and their first impulse is to remove its limited intelligence, which is embedded in programs called HESPER (Heuristic Self-Programming Extendable Routine). The alternative is the exact opposite: to install something like FISE (Functional Integration using Simulated Environment), which is under development, thereby equipping the program with more intelligence and some plain old "common sense." The problem with this otherwise attractive idea is stated by Dr Raymond Dyer, an AI expert and the book's protagonist:

> "If an enhanced TITAN ever evolved the motivational drive to preserve its own existence, the very

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fact that it's a rational system would enable it to devise very effective ways of going about it. Also, since it's an extremely powerful learning machine that operates at computer speeds, once it started to do something, it would do it very fast! If the machine interpreted agencies in the universe around it as constituting real or imagined threats to its existence, then the rational thing for it to do would be to experiment until it identified measures that were effective in neutralizing those agencies . . . . If one of them turned out to be us or our vital interests, we could have real problems."

The team decides to investigate the "increased intelligence" approach carefully, but not on Earth—it's too dangerous. Instead, a superdistributed computer system incorporating many processors is installed on a giant space station (built with metal from the mass driver, of course) and provided with a "survival instinct" and FISE-like intelligent programs. Spartacus (the system's name) is also given control of small flying machines, called "drones," that allow it to repair itself. Then Spartacus is deliberately attacked. The first attack is simple—one of its main processors is switched off. When Spartacus solves this problem, the attacks become more direct.

Elaborate safeguards have been provided to insure that the people always have the upper hand. As a last resort, they can always "pull the plug" on Spartacus by knocking out its power source. However, the safeguards prove to be inadequate—the computer arranges to take the humans with it if the power source is knocked out. The last one hundred pages are quite exciting. Fighting escalates until a situation arises wherein the battle-scarred space station will be destroyed unless man and machine cooperate. They do, and everybody lives happily ever after. (Yes, this is a deus ex machina—in more ways than one!)

Spartacus, P-1, and Artificial Intelligence

The major differences between Hogan's Spartacus and Ryan's P-1 can be summarized in one sentence: P-1 has far less going for it than Spartacus, but ends up knowing much more. Spartacus' accomplishments are about what I'd expect from the circumstances Hogan describes; hence, P-1's are wildly improbable. I'll return to this comparison after laying a foundation for it.

Ryan makes no claims for Gregory Burgess' brilliance; in fact, he states that Burgess is *not* a genius. When P-1 breaks loose from its creator and only teacher, it apparently has no knowledge of natural language or of the real world. But by the time P-1 reestablishes contact with Burgess, the computer speaks English like a native and knows a lot about the world.

In one instance, P-1 amazes everyone by turning its hardware off and then back on:

> how did you do that?
>
> THAT IS THE ENGINEERING CHANGE THAT WAS INSTALLED NOVEMBER 2, 1976. I THOUGHT THAT WOULD IMPRESS YOU.
>
> it did.
>
> THE DIFFICULT PART IS POWERING THE SYSTEM BACK UP.
>
> yes. i said i was impressed.
>
> I WOULD BE IMPRESSED IF YOU UNDERSTOOD THE DIFFICULTY.
>
> we all have some limitations.
>
> YES. ANY FURTHER QUESTIONS?

To understand why this display of knowledge is so hard to believe, the reader needs to know something of what has been learned about artificial intelligence thus far. While I can't say as much about AI here as I would like to, let me say that researchers have made significant progress over the last twenty-five years on the closely related problems of natural-language understanding and world understanding, and are studying machine learning done with or without a (human) teacher. At this point, however, no one is near able to write a program that understands English like a third grader, let alone an

adult, nor does anyone know how to write a program that can learn such a sophisticated skill.

Arthur Samuel's well-known checkers program is an actual example of a self-taught computer program. The program played so poorly at first that a child could beat it: it reached championship caliber only after playing thousands of games, just as a person would. An example of a program that needs a teacher is Patrick Winston's program that "learns to recognize structures such as tables, arches, pedestals, and arcades by being shown examples and counterexamples of them. The program's teacher has to tell it which is which, but does not have to say why: the program itself spontaneously searches for the difference that makes the difference." (See reference 3. The interested reader should also see Douglas Hofstadter's *Gödel, Escher, Bach: An Eternal Golden Braid*, or Margaret Boden's *Artificial Intelligence and Natural Man.*)

P-1 has at its disposal more memory and computing speed than any computer in existence by a factor of perhaps 250. (When P-1 contacts Gregory Burgess, the machine has 20,195 systems, all presumably IBM 360s, under its control. With a total of 5805 megabytes of storage, making reasonable assumptions about the speed of an "average" 360, and taking the CYBER 205 as the largest and fastest computer in existence, I came up with a ratio of about 250 to 1. Either 25 or 2500 might be more accurate; it doesn't matter.) By now, however, it has become obvious that brute force is an ineffective way to achieve intelligence. Example: a computer could, in theory, play flawless chess by examining all possible moves and replies to moves to the end of the game. It could then choose the best move—an easy task with so much information. The insurmountable problem with this approach is that there are, by conservative estimates, 10^{120} possibilities, which would take at least 10^{105} years to compute at the speed of the CDC CYBER 205 supercomputer. A factor of 250 doesn't make a dent in a number like that.

P-1 is said to have read the complete works of Shakespeare, Conan Doyle, Faulkner, etc, and it reads the *Los Angeles Times*, the *Washington Post*, and the *New York Times* every day. All are made available by computer typesetting. Unfortunately P-1, unaided, would be unable to get anything out of these. It could recognize words and quickly look them up in a dictionary, but this wouldn't put P-1 any closer to real understanding, as authors of early dictionary-based translation programs discovered (see reference 4). *If* P-1 could reach third-grade understanding of English, it might be able to use children's literature to bring itself up to adult level. But P-1 couldn't reach third-grade level, not even with a teacher and certainly not by itself. So Ryan's use of the verb "to read" is misleading.

Ryan leans heavily on the self-teaching matchboxes technique to get Burgess' project off the ground before P-1 even comes into existence. This technique works for something as simple as tic-tac-toe, but that's about all. In fairness to Ryan, he never claims that the matchbox

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technique is anything but a way to speed up Gregory's search for a supervisor-cracking method; on the other hand, there is no meaningful description of his method.

Ryan could have set his story in the 1990s, made the computers IBM 390s instead of 360s, and had Burgess be a genius, thus giving some measure of plausibility to his fiction. These changes are so minor that they could almost be made mechanically with a text editor (assuming that the manuscript was machine readable), leaving the rest of the book untouched.

Hogan's Spartacus gains its abilities in a far more realistic way. As a parallel, one of the outstanding achievements of real AI is Terry Winograd's SHRDLU, a program that works with an imaginary world of blocks of various sizes, shapes, and colors, all sitting on a tabletop, the entire scene displayed on a CRT. SHRDLU can converse about this "microworld" in completely natural English (in writing, via keyboard and CRT). SHRDLU can take orders to do various things with the blocks, many of the tasks requiring fairly complex problem-solving strategies, and can answer questions about the microworld or about its own actions. In short, SHRDLU appears to understand this simple little world as well as a human would (see reference 5).

TFT's FISE is, apparently, a sophisticated descendant of SHRDLU. Its toy world has a man, named Hector, living in a house with his dog and attacking such problems as how to cook eggs without mixing in the butter wrapper and pieces of eggshell. FISE's emphasis seems to be more on problem solving and less on natural language, as the following excerpt shows. To set the stage, Chris and Ron are computer scientists, associates of Dyer's, and Laura is a reporter getting a demonstration. Here, Hector has carefully placed the intact egg in the frying pan.

> "How are you going to eat the egg when you've fried it?" At the console, Chris silently translated Ron's question into touchboard commands.
>
> "With the knife and fork, off the plate, on the table," FISE replied proudly.
>
> "Very good, FISE," Ron approved in dulcet tones. Then his voice began on a slightly higher note and rose rapidly to end in a shriek. "How are you going to cut the egg with the knife when it's still inside the goddam shell?" Chris conveyed the essential information via the console.
>
> "I wasn't very sure about that," FISE confessed. "But you told me I wasn't supposed to break eggs."
>
> "It's okay to break an egg if you want to fry it," Ron said, having regained his composure. Hector promptly picked the egg out of the pan, crushed it in his fist and held it out for the resulting mess to drip back into the pan. Laura made a face and gave an involuntary exclamation of disgust.
>
> "Now you can see the kind of thing I meant," Dyer commented. "Totally rational solutions but no commonsense constraints."

(Incidentally, the first hundred pages of *TFT* provide a painless introduction to AI, suitable even for the computer illiterate.)

We are now ready to reconsider the relative plausibility of P-1 and Spartacus. Since P-1's ill-defined "creativity" element must be considered, the comparison is difficult, but let's assume the two machines start with equal assets. If anything, this decision favors P-1. Remember that P-1 is on its own until it recontacts Burgess, displaying at that time fully developed intelligence: it sounds like a well-educated, intelligent adult. On the other hand, experts confront Spartacus with a series of escalating problems, and it thereby learns a great deal. In spite of this, Spartacus doesn't begin to approach P-1's knowledge or command of English. In fact, no knowledge of natural language is claimed for Spartacus. Q E D.

Conclusions

AP-1's basic concept, an intelligent and powerful but immature computer, is not original: it appears in the earlier *When Harlie Was One* (see reference 6). I know of no reason why this idea could not be presented in a technically competent way, but unfortunately *When Harlie Was One* is, if anything, worse than *AP-1*. It commits the unpardonable sin of claiming that special hardware—called "judgment circuits"—is required to make a computer intelligent, then tries to use this claim as an *explanation* of how the machine works. But, in fact,

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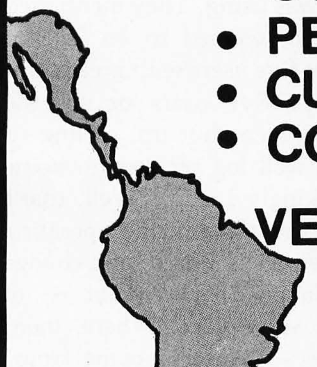

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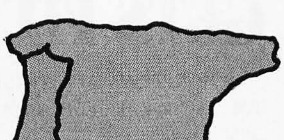

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anything that can be done with hardware can be done with software, and vice versa. And *When Harlie Was One* makes only a feeble attempt to explain how judgment circuits work. This is understandable, because the idea that intelligent judgment can be neatly packaged is ridiculous.

Ultimately, what bothers me about *AP-1*, *When Harlie Was One*, and TV series that depict anthropomorphic intelligent machines, is not so much that they misrepresent machine intelligence as that they fail to understand the nature of *any* intelligence. No one knows in any detail how intelligent behavior can ultimately be pulled out of the rigid, inflexible, unthinking hardware of the computer: I certainly don't. But we do know where some of the complexity of intelligence lies and how complicated it is. I regret that much of the fiction about intelligent machines shows no understanding of these facts.

An outstanding example of an area whose complexity is now quite clear is natural language. Boden (see reference 7) makes several relevant comments on this subject:

> Cineastes will remember Stanley Kubrick's film of Arthur Clarke's *2001, A Space Odyssey* as a rich source of prophecies concerning technological advance. If asked to list the more fanciful of these futuristic suggestions, probably few would mention the sensible verbal exchanges between the human astronauts and HAL, the computer. HAL's linguistic prowess is more commonly taken for granted than is the basically trivial gadgetry compensating for weightlessness. And the tortured nursery rhymes emitted by the computer while its circuitry is hacked to pieces stay more vividly in the memory than do HAL's earlier conversations with his English-speaking interlocutors. HAL's ability to lip-read is indeed surprising, but his appropriate replies to the indefinitely various remarks of the human crew cause scarcely an eyebrow to rise in wonderment.
>
> This common pattern of response on the part of the filmgoer is a prime example of straining at gnats while swallowing a camel. Understanding one's native language is apparently effortless and introspectively simple, but in fact involves the deployment of intellectual capacities of an extraordinary complexity. The project of programming a machine to simulate such comprehension not only promises a corresponding complexity, but also presupposes a theoretically explicit understanding of understanding.

Two other phenomena that are extremely complex are judgment and creativity. Judgment circuits? Creativity modules? Here I'm going out on a limb, but I don't believe that judgment and creativity are processes that can be neatly packaged. They are what Hofstadter calls "epiphenomena," resulting from the organization of a complex system and not residing in any specific part of it. Hofstadter (see reference 8) gives some good examples of epiphenomena:

> I was talking one day with two systems programmers for the computer I was using. They mentioned that the operating system seemed to be able to handle up to about thirty-five users with great comfort, but at about thirty-five users or so, the response time all of a sudden shot up, getting so slow that you might as well log off and go home and wait until later. Jokingly I said, "Well, that's simple to fix—just find the place in the operating system where the number '35' is stored, and change it to '60'!" Everyone laughed. The point is, of course, that there is no such place. Where, then, does the critical number—35 users—come from? The answer is: *It is a visible consequence of the overall system organization—an "epiphenomenon."*
>
> Similarly, you might ask about a sprinter, "Where is the '9.3' stored, that makes him be able to run 100 yards in 9.3 seconds?" Obviously, it is not stored anywhere. His time is a result of how he is built, what his reaction time is, a million factors all interacting when he runs. The time is quite reproducible, but it is not stored in his body anywhere. It is spread around among all the cells of his body and only manifests itself in the act of the sprint itself.

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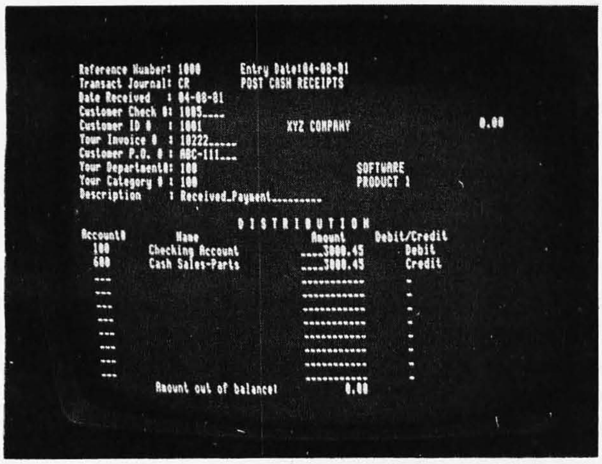

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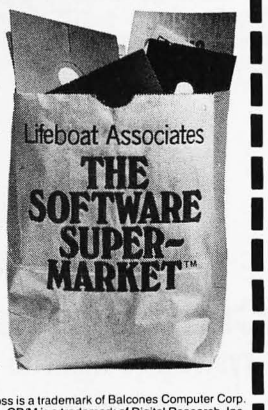

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I'd like to make clear that I don't object to science fiction that makes use of computers, intelligent or otherwise, without explaining how they work. HAL in *2001: A Space Odyssey* is basically of this type, though I think the year 2001 is much too early for the human-or-better intelligence HAL displays. Boden, who repeatedly uses HAL as a standard of true intelligence in a machine, apparently agrees on both comments. Another example is Ellison's *I Have No Mouth and I Must Scream*, which postulates a computer that goes berserk. It kills everyone in the world, except for five people whom it plans to keep alive to torture forever. Unpleasant and unlikely, but the story doesn't say how the computer works and how it was developed, so my understanding of intelligence is not contradicted.

In *The Cybernetic Imagination in Science Fiction*, Warrick concludes that "with too few exceptions, the fiction gives no evidence that it is aware of information theory or computer technology . . . the portrayal of computer technology is too often inaccurate and distorted . . . ." I agree. She then speculates that "the complex, technical nature of the material in computer science and the incredible speed of developments in the field make it impossible for the literary imagination to keep abreast of the material." This I do not believe. I like Ted Nelson's comment that any nitwit can understand computers, and many do. "Understand" does not mean "be an expert on"; that is something that takes talent and time, for the reasons Warrick mentions. My own speculation is that many science-fiction writers misrepresent computers because they *think* computers are hard to understand, and as a result they don't really try. Perhaps they feel, consciously or otherwise, that there's no point in really understanding computers, since the real thing will be too complicated for their readers.

There is also, as I have already suggested, an even more important distorting factor in the science fiction about *intelligent* computers. Although it sounds obvious when stated directly, I think this point is often forgotten: machine intelligence is just a type of intelligence. Therefore writers about intelligent machines need to understand something about intelligence. In my opinion, they need this more than they need to understand computers. ■

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Symbolic Differentiation à la LISP

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Just as I would not consider repairing a car with only a screwdriver and wrench in hand, so would I also not approach the art of computer programming with but a few computer languages in mind. It is clear that each well-known language has a forte, otherwise it would have faded into obscurity. But in the realm of symbolic mathematics, LISP and its descendants stand alone. As a vehicle for the development of symbolic-mathematical code, LISP is the natural choice.

Background

Two years ago I had not heard of LISP, and it was not until I read the August 1979 BYTE, a LISP theme issue, that I first realized the power of the language. At that time, however, there were no LISP interpreters available for the Radio Shack TRS-80. This prompted me to spend the next ten months writing a complete LISP interpreter, which proved an interesting and educational undertaking. The resulting interpreter fits comfortably in a 16 K-byte TRS-80 Model I computer.

About the Author

Lt Ronald L Nicol was stationed at the Naval Research Laboratory in Washington DC and, later, aboard the USS M G Vallejo *as Reactor Controls Officer and Main Propulsion Assistant. Currently, he is a Chemistry and Material Science Instructor at the Naval Nuclear Power School.*

As I soon learned, a necessary condition to writing a LISP interpreter and eventually writing effective LISP programs is the use of recursion. Few languages take such full advantage of recursion. The resulting interpreter incorporates approximately fifty machine-code LISP functions, including the PROG feature and the FUNARG device (a method of specifying variable bindings, or assignments), and a form of virtual memory.

In the realm of symbolic mathematics, LISP and its descendants stand alone.

As a preface to the discussion of the symbolic differentiation program, I will discuss a mechanism called the *association list*, or *A-list*, used in most LISP systems. The A-list exists as a software stack that holds variable bindings. A common approach, and one which I used, is to create a list of pairs, each containing the name and value of a variable. When the value of a variable is required, the A-list is searched from the top down, and the value of the first occurrence of the variable is returned. There are many distinct advantages to this treatment, one of which is that variables can be made completely local with respect to a function. This is accomplished by virtue of the fact that a function binds its variables before operating on them, and removes the bindings when the function is complete. In tandem with modular definition of functions, this feature allows full recursion—a function may call itself any number of times.

There are two types of user-defined functions in LISP. One is the EXPR-type function, which has its arguments evaluated, while the other type, the FEXPR function, does not have its arguments evaluated. Of the two arguments passed to a FEXPR function, the first is a list consisting of user arguments and the second is the A-list. Passing the A-list as an argument allows FEXPR functions to preserve the calling environment.

A property list is associated with each atom. The FEXPR and EXPR function definitions are contained in the property list so that the interpreter can properly evaluate a function.

The first step in developing a usable LISP symbolic-math system is to define the defining functions. Listing 1 contains the functions DEF and DFF. The DEF function is the EXPR defining function, and DFF is the FEXPR defining function. Both functions operate by placing the function definition on the property list of the given function name, under the appropriate atomic indicator. Note

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Listing 1: *Defining the defining functions. The function definitions are placed on the property lists of DEF and DFF. Functions defined using DEF have their arguments evaluated, while those defined with DFF do not.*

```
(PUTPROP(QUOTE DEF)
  (QUOTE(LAMBDA(S A)
        (PUTPROP(CAR S)
          (CONS LAMBDA(CDR S))
          EXPR)))
  FEXPR)
(PUTPROP(QUOTE DFF)
  (QUOTE(LAMBDA(S A)
        (PUTPROP(CAR S)
          (CONS LAMBDA(CDR S))
          FEXPR)))
  FEXPR)
```

that both of these functions exist as FEXPR functions on the DEF and DFF atoms, respectively.

When it is occasionally necessary to use special LISP characters in a context different from their meanings in LISP, the double-quote convention is used (eg: to parse "−" as a minus sign instead of a negative zero). Use of this feature is illustrated as follows:

```
(QUOTE −) = 0
(QUOTE "−") = −
(QUOTE +) = 0
(QUOTE "+") = +
```

Additionally, the functions ADD and SUB are, respectively, the two-argument special-case functions of the standard LISP functions PLUS and DIFFERENCE.

System Overview

The symbolic differentiator consists of three sections: the input parser, the differentiating function, and the output parser. This process is shown symbolically in figure 1. The purpose of the input parser is to translate user input from normal mathematical infix notation to Cambridge prefix notation, the notation used by LISP. The differentiating function differentiates the output, which is subsequently converted back to infix notation by the output parser.

Input

The input function, PREF, consists of a *recursive descent parser* with no backtracking. Michael Tucker, a fellow LISP enthusiast, and I wrote this function in a matter of twenty minutes, a point that attests to the clarity and lucidity of LISP programming. A recursive descent parser determines which of two operators has higher priority, breaks the input into two sections, and calls itself on each of the pieces. The *no-backtracking* characteristic means that the parser does not have to scan back to check priority.

PREF was designed with the flexibility to change operator precedence. Each binary operator has a left binding power, LB, and a right binding power, RB. By comparing the left and right binding powers of the operators competing for an argument, the parser decides which operator wins the argument. If the left and right binding powers of the operators are equal, the operator on the left of the argument wins. The values of left and right binding powers are stored on the property list of the operator under the indicators LB and RB, respectively. Also contained on the property list of each operator under the indicator OP is the equivalent LISP function name. For example, the property list of the multiplication operator * might appear as follows:

((OP,TIMES)(LB,60)(RB,80))

Listing 2: *Definition of the function SETUP, which assigns the left and right binding powers to binary operators and places the appropriate property on the indicator OP for unary operators. The auxiliary function MAPCAR maps the second argument onto successive CARs of the first argument.*

```
(DEF SETUP( )
  (PROG( )
    (MAPCAR(QUOTE((↑ 90 100 EXPT)
                  (* 60 80 TIMES)
                  (/ 50 70 DIV)
                  ("+" 20 40 ADD)
                  ("−" 10 30 SUB)))
        (QUOTE(LAMBDA(L)
                  (PROG( )
                    (PUTPROP(CAR L)
                      (CAR(CDR L))
                      (QUOTE LB))
                    (PUTPROP(CAR L)
                      (CAR(CDR(CDR L)))
                      (QUOTE RB))
                    (PUTPROP(CAR L)
                      (CAR(CDR(CDR(CDR L))))
                      (QUOTE OP))))))
    (PUTPROP(QUOTE COS)
      (QUOTE COS)
      (QUOTE OP))
    (PUTPROP(QUOTE SIN)
      (QUOTE SIN)
      (QUOTE OP))
    (PUTPROP(QUOTE EXP)
      (QUOTE EXP)
      (QUOTE OP))
    (PUTPROP(QUOTE LOG)
      (QUOTE LOG)
      (QUOTE OP))))
```

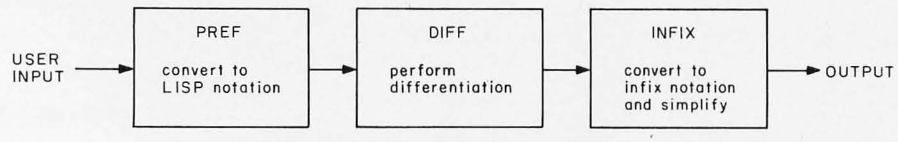

Figure 1: *Skeletal structure of the symbolic-differentiating system. Each block represents a recursive function that performs the task denoted within.*

Operator precedence is initially set by executing the function SETUP, which is given in listing 2. The user, however, may at any time alter operator precedence by changing the LB or RB value of an operator by means of the LISP PUTPROP function. Unary operators and single-operator functions are treated by placing the function within parentheses. The input parser, PREF, is defined in listing 3. The power of this function lies in its ability to recursively call itself. Table 1 contains examples illustrating the use of PREF.

Input	Output
(PREF(QUOTE(A * B "+" C)))	(ADD(TIMES A B)C)
(PREF(QUOTE(A *(B "+" C))))	(TIMES A(ADD B C))
(PREF(QUOTE(A "−" B ↑ C)))	(SUB A(EXPT B C))
(PREF(QUOTE(1 /(N !))))	(DIV 1(FAC N))
(PREF(QUOTE("−" Y)))	(SUB 0 Y)
(PREF(QUOTE(X *(COS X / 2))))	(TIMES X(COS(DIV X 2)))

Table 1: *Sample input and output of the function PREF, which converts infix notation to prefix notation.*

Differentiation

Unlike other areas of mathematics, such as integration or theorem proving, differentiation can generally be characterized by a finite set of definite, rigorous rules, which may easily be defined as recursive LISP functions (see table 2). The differentiating function, DIFF, receives two arguments: the expression to be differentiated and the variable with

Listing 3: *Definition of the recursive descent parser, PREF. The parser is defined without backtracking, which minimizes memory and time requirements.*

```
(DEF PREF(E)
  (COND((ATOM E)E)
    ((NULL(CDR E))(PREF(CAR E)))
    ((COND((ATOM(CAR E))(GET(CAR E)(QUOTE OP))))
      (COND((EQ(CAR E)(QUOTE "-"))
          (LIST(QUOTE SUB)
            0
            (PREF(CDR E))))
        (T(LIST(GET(CAR E)(QUOTE OP))
            (PREF(CDR E))))))
    ((EQ(CAR(CDR E))(QUOTE !))
      (LIST(QUOTE FAC)
        (PREF(CAR E))))
    ((NULL(CDR(CDR(CDR E))))
      (LIST(GET(CAR(CDR E))(QUOTE OP))
        (PREF(CAR E))
        (PREF(CDR(CDR E)))))
    ((GREATER(GET(CAR(CDR(CDR(CDR E))))(QUOTE LB))
          (GET(CAR(CDR E))(QUOTE RB)))
      (LIST(GET(CAR(CDR E))(QUOTE OP))
        (PREF(CAR E))
        (PREF(CDR(CDR E)))))
    (T(LIST(GET(CAR(CDR(CDR(CDR E))))(QUOTE OP))
        (PREF(LIST(CAR E)
            (CAR(CDR E))
            (CAR(CDR(CDR E)))))
        (PREF(CDR(CDR(CDR(CDR E)))))))))
```

respect to which the differentiation is to occur. DIFF appears in listing 4.

The function DIFF first tests whether or not the expression is an atom. If so, it determines if the expression is the variable of interest, in which case the value of the function is 1, because the derivative of a variable with respect to itself is unity. Otherwise, if the argument to DIFF is some other atom, 0 is returned. The additional clauses of the DIFF COND statement search for more complex differentiating rules which may be satisfied. The rules are applied recursively, which allows for the simple LISP representation. The modularity of this LISP function is obvious. It is easily extensible to encompass additional rules by the inclusion of additional clauses to the COND. Considering DIFF as a black box, table 3 lists exemplary input and output of the function.

Output

Once DIFF has mapped its input into the appropriate derivative, it is

Text continued on page 230
Listing 4 and Table 2 are on page 224
Listing 5 is on page 226

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Listing 4: *The definition of the differentiating function DIFF. It consists of a COND statement (LISP's version of the* case *statement) in which each clause checks for a particular differentiating rule. Recursion is used extensively.*

```
(DEF DIFF(E X)
  (COND((ATOM E)(COND((EQ E X)1)(T 0)))
    ((EQ(CAR E)(QUOTE ADD))
      (LIST(QUOTE ADD)
        (DIFF(CAR(CDR E))X)
        (DIFF(CAR(CDR(CDR E)))X)))
    ((EQ(CAR E)(QUOTE TIMES))
      (LIST(QUOTE ADD)
        (LIST(QUOTE TIMES)
          (CAR(CDR E))
          (DIFF(CAR(CDR(CDR E)))X))
        (LIST(QUOTE TIMES)
          (CAR(CDR(CDR E)))
          (DIFF(CAR(CDR E))X))))
    ((EQ(CAR E)(QUOTE SIN))
      (LIST(QUOTE TIMES)
        (LIST(QUOTE COS)
          (CAR(CDR E)))
        (DIFF(CAR(CDR E))X)))
    ((EQ(CAR E)(QUOTE COS))
      (LIST(QUOTE TIMES)
        (LIST(QUOTE SUB)
          0
          (LIST(QUOTE SIN)
            (CAR(CDR E))))
        (DIFF(CAR(CDR E))X)))
    ((EQ(CAR E)(QUOTE DIV))
      (LIST(QUOTE DIV)
        (LIST(QUOTE SUB)
          (LIST(QUOTE TIMES)
            (CAR(CDR(CDR E)))
            (DIFF(CAR(CDR E))X))
          (LIST(QUOTE TIMES)
            (CAR(CDR E))
            (DIFF(CAR(CDR(CDR E)))X)))
        (LIST(QUOTE TIMES)
          (CAR(CDR(CDR E)))
          (CAR(CDR(CDR E))))))
    ((EQ(CAR E)(QUOTE SUB))
      (LIST(QUOTE SUB)
        (DIFF(CAR(CDR E))X)
        (DIFF(CAR(CDR(CDR E)))X)))
    ((EQ(CAR E)(QUOTE EXPT))
      (LIST(QUOTE ADD)
        (LIST(QUOTE TIMES)
          (DIFF(CAR(CDR E))X)
          (LIST(QUOTE TIMES)
            (CAR(CDR(CDR E)))
            (LIST(QUOTE EXPT)
              (CAR(CDR E))
              (LIST(QUOTE SUB)
                (CAR(CDR(CDR E)))
                1))))
        (LIST(QUOTE TIMES)
          (DIFF(CAR(CDR(CDR E)))X)
          (LIST(QUOTE TIMES)
            (LIST(QUOTE LOG)
              (CAR(CDR E)))
            (LIST(QUOTE EXPT)
              (CAR(CDR E))
              (CAR(CDR(CDR E))))))))
    ((EQ(CAR E)(QUOTE EXP))
      (LIST(QUOTE TIMES)
        E
        (DIFF(CAR(CDR E))X)))
    ((EQ(CAR E)(QUOTE LOG))
      (LIST(QUOTE TIMES)
        (LIST(QUOTE DIV)
          1
          (CAR(CDR E)))
        (DIFF(CAR(CDR E))X)))))
```

$$\frac{d}{dx}(a) = 0$$

$$\frac{d}{dx}(x) = 1$$

$$\frac{d}{dx}(u + v) = \frac{du}{dx} + \frac{dv}{dx}$$

$$\frac{d}{dx}(uv) = u\frac{dv}{dx} + v\frac{du}{dx}$$

$$\frac{d}{dx}(\sin u) = \frac{du}{dx}(\cos u)$$

$$\frac{d}{dx}(\cos u) = -\frac{du}{dx}(\sin u)$$

$$\frac{d}{dx}(u/v) = \frac{\left(v\frac{du}{dx} - u\frac{dv}{dx}\right)}{v^2}$$

$$\frac{d}{dx}(u - v) = \frac{du}{dx} - \frac{dv}{dx}$$

$$\frac{d}{dx}(u^v) = vu^{v-1}\frac{du}{dx} + (\log u)\,u^v\frac{dv}{dx}$$

$$\frac{d}{dx}(e^u) = e^u\frac{du}{dx}$$

$$\frac{d}{dx}(\log u) = \frac{1}{u}\frac{du}{dx}$$

Table 2: *A summary of the rules of differentiation used by DIFF. The terms* u *and* v *represent functions of* x, *while* a *represents a real number.*

Listing 5: *The function definition of INFIX, the output parser. INFIX converts its input from Cambridge prefix notation to mathematical infix notation. INFIX also performs algebraic simplification.*

```
(DEF INFIX(E)
  (COND((ATOM E)E)
    (T(PROG(FIRST SECOND)
          (SETQ FIRST(INFIX(CAR(CDR E))))
          (COND((CDR(CDR E))
               (SETQ SECOND(INFIX(CAR(CDR(CDR E)))))))
          (RETURN
            (COND((EQ(CAR E)(QUOTE ADD))
                 (COND((EQ FIRST 0)SECOND)
                   ((EQ SECOND 0)FIRST)
                   ((TWONUM)(EVAL E NIL))
                   ((EQUAL FIRST SECOND)
                     (LIST 2
                       (QUOTE *)
                       FIRST))
                   ((MATCH(LIST(QUOTE ?)(QUOTE *)FIRST)SECOND)
                     (INFIX(LIST(QUOTE TIMES)
                                (LIST(QUOTE ADD)
                                  (CAR SECOND)
                                  1)
                                FIRST)))
                   ((MATCH(LIST(QUOTE ?)(QUOTE *)SECOND)FIRST)
                     (INFIX(LIST(QUOTE TIMES)
                                (LIST(QUOTE ADD)
                                  (CAR FIRST)
                                  1)
                                SECOND)))
                   (T(LIST FIRST
                       (QUOTE "+")
                       SECOND))))
               ((EQ(CAR E)(QUOTE TIMES))
                 (COND((EQ FIRST 1)SECOND)
                       ((EQ SECOND 1)FIRST)
                       ((EQ FIRST 0)0)
                       ((EQ SECOND 0)0)
                       ((EQUAL FIRST SECOND)
                         (LIST FIRST
                           (QUOTE ↑)
                           2))
                       ((TWONUM)(EVAL E NIL))
                       ((MATCH(LIST FIRST(QUOTE ↑)(QUOTE ?))SECOND)
                         (INFIX(LIST(QUOTE EXPT)
                                FIRST
                                (LIST(QUOTE ADD)
                                  (CAR(CDR(CDR SECOND)))
                                  1))))
                       ((MATCH(LIST SECOND(QUOTE ↑)(QUOTE ?))FIRST)
                         (INFIX(LIST(QUOTE EXPT)
                                SECOND
                                (LIST(QUOTE ADD)
                                (CAR(CDR(CDR FIRST)))
                                1))))
                       ((MATCH(LIST(QUOTE ?)(QUOTE *)FIRST)SECOND)
                         (INFIX(LIST(QUOTE TIMES)
                                (CAR SECOND)
                                (LIST(QUOTE EXPT)
                                  FIRST
                                  2))))
                       ((MATCH(LIST(QUOTE ?)(QUOTE *)SECOND)FIRST)
                         (INFIX(LIST(QUOTE TIMES)
                                (CAR FIRST)
                                (LIST(QUOTE EXPT)
                                  SECOND
                                  2))))
```

Listing 5 continued on page 228

Listing 5 continued:

```
      (T(LIST FIRST
           (QUOTE *)
           SECOND))))
((EQ(CAR E)(QUOTE DIV))
  (COND((EQ SECOND 1)FIRST)
       ((EQUAL FIRST SECOND)1)
       ((EQ FIRST 0)0)
       ((TWONUM)(EVAL E NIL))
       ((MATCH(LIST(QUOTE ?)(QUOTE *)SECOND)FIRST)
        (INFIX(LIST(QUOTE TIMES)
               (LIST(QUOTE SUB)
                 (CAR FIRST)
                 1)
               SECOND)))
       ((MATCH(LIST(QUOTE ?)(QUOTE *)FIRST)SECOND)
        (INFIX(LIST(QUOTE DIV)
               1
               (LIST(QUOTE TIMES)
                 (LIST(QUOTE SUB)
                   (CAR SECOND)
                   1)
                 FIRST))))
       ((MATCH(LIST SECOND(QUOTE ↑)(QUOTE ?))FIRST)
        (INFIX(LIST(QUOTE EXPT)
               SECOND
               (LIST(QUOTE SUB)
                 (CAR(CDR(CDR FIRST)))
                 1))))
       ((MATCH(LIST FIRST(QUOTE ↑)(QUOTE ?))SECOND)
        (INFIX(LIST(QUOTE DIV)
               1
               (LIST(QUOTE EXPT)
                 FIRST
                 (LIST(QUOTE SUB)
                   (CAR(CDR(CDR SECOND)))
                   1)))))
       (T(LIST FIRST
           (QUOTE /)
           SECOND))))
((EQ(CAR E)(QUOTE EXPT))
  (COND((EQ SECOND 1)FIRST)
       ((EQ SECOND 0)1)
       ((TWONUM)(EVAL E NIL))
       (T(LIST FIRST
           (QUOTE ↑)
           SECOND))))
((EQ(CAR E)(QUOTE SUB))
  (COND((EQ SECOND 0)FIRST)
       ((EQ FIRST 0)(LIST(QUOTE "-")
                     SECOND))
       ((TWONUM)(EVAL E NIL))
       ((EQUAL FIRST SECOND)0)
       (T(LIST FIRST
           (QUOTE "-")
           SECOND))))
((EQ(CAR E)(QUOTE LOG))
  (COND((EQ FIRST 1)0)
       (T(LIST(QUOTE LOG)
           FIRST))))
    ((EQ(CAR E)(QUOTE SIN))
      (LIST(QUOTE SIN)
        FIRST))
    ((EQ(CAR E)(QUOTE COS))
      (LIST(QUOTE COS)
        FIRST))
    ((EQ(CAR E)(QUOTE EXP))
      (COND((EQ FIRST 0)1)
           (T(LIST(QUOTE EXP)
             FIRST))))
```

Listing 5 continued on page 230

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1	RULE78	Interest Apportionment by Rule of the 78's
2	ANNU1	Annuity computation program
3	DATE	Time between dates
4	DAYYEAR	Day of year a particular date falls on
5	LEASEINT	Interest rate on lease
6	BREAKEVN	Breakeven analysis
7	DEPRSL	Straightline depreciation
8	DEPRSY	Sum of the digits depreciation
9	DEPRDB	Declining balance depreciation
10	DEPRDDB	Double declining balance depreciation
11	TAXDEP	Cash flow vs. depreciation tables
12	CHECK2	Prints NEBS checks along with daily register
13	CHECKBK1	Checkbook maintenance program
14	MORTGAGE/A	Mortgage amortization table
15	MULTMON	Computes time needed for money to double, triple, etc.
16	SALVAGE	Determines salvage value of an investment
17	RRVARIN	Rate of return on investment with variable inflows
18	RRCONST	Rate of return on investment with constant inflows
19	EFFECT	Effective interest rate of a loan
20	FVAL	Future value of an investment (compound interest)
21	PVAL	Present value of a future amount
22	LOANPAY	Amount of payment on a loan
23	REGWITH	Equal withdrawals from investment to leave 0 over
24	SIMPDISK	Simple discount analysis
25	DATEVAL	Equivalent & nonequivalent dated values for oblig.
26	ANNUDEF	Present value of deferred annuities
27	MARKUP	% Markup analysis for items
28	SINKFUND	Sinking fund amortization program
29	BONDVAL	Value of a bond
30	DEPLETE	Depletion analysis
31	BLACKSH	Black Scholes options analysis
32	STOCVAL1	Expected return on stock via discounts dividends
33	WARVAL	Value of a warrant
34	BONDVAL2	Value of a bond
35	EPSEST	Estimate of future earnings per share for company
36	BETAALPH	Computes alpha and beta variables for stock
37	SHARPE1	Portfolio selection model-i.e. what stocks to hold
38	OPTWRITE	Option writing computations
39	RTVAL	Value of a right
40	EXPVAL	Expected value analysis
41	BAYES	Bayesian decisions
42	VALPRINF	Value of perfect information
43	VALADINF	Value of additional information
44	UTILITY	Derives utility function
45	SIMPLEX	Linear programming solution by simplex method
46	TRANS	Transportation method for linear programming
47	EOQ	Economic order quantity inventory model
48	QUEUE1	Single server queueing (waiting line) model
49	CVP	Cost-volume-profit analysis
50	CONDPROF	Conditional profit tables
51	OPTLOSS	Opportunity loss tables
52	FQUOQ	Fixed quantity economic order quantity model

	NAME	DESCRIPTION
53	FQEOWSH	As above but with shortages permitted
54	FQEOQPB	As above but with quantity price breaks
55	QUEUECB	Cost-benefit waiting line analysis
56	NCFANAL	Net cash-flow analysis for simple investment
57	PROFIND	Profitability index of a project
58	CAP1	Cap. Asset Pr. Model analysis of project
59	WACC	Weighted average cost of capital
60	COMPBAL	True rate on loan with compensating bal. required
61	DISCBAL	True rate on discounted loan
62	MERGANAL	Merger analysis computations
63	FINRAT	Financial ratios for a firm
64	NPV	Net present value of project
65	PRINDLAS	Laspeyres price index
66	PRINDPA	Paasche price index
67	SEASIND	Constructs seasonal quantity indices for company
68	TIMETR	Time series analysis linear trend
69	TIMEMOV	Time series analysis moving average trend
70	FUPRINF	Future price estimation with inflation
71	MAILPAC	Mailing list system
72	LETWRT	Letter writing system-links with MAILPAC
73	SORT3	Sorts list of names
74	LABEL1	Shipping label maker
75	LABEL2	Name label maker
76	BUSBUD	DOME business bookkeeping system
77	TIMECLCK	Computes weeks total hours from timeclock info.
78	ACCTPAY	In memory accounts payable system-storage permitted
79	INVOICE	Generate invoice on screen and print on printer
80	INVENT2	In memory inventory control system
81	TELDIR	Computerized telephone directory
82	TIMUSAN	Time use analysis
83	ASSIGN	Use of assignment algorithm for optimal job assign.
84	ACCTREC	In memory accounts receivable system-storage ok
85	TERMSPAY	Compares 3 methods of repayment of loans
86	PAYNET	Computes gross pay required for given net
87	SELLPR	Computes selling price for given after tax amount
88	ARBCOMP	Arbitrage computations
89	DEPRSF	Sinking fund depreciation
90	UPSZONE	Finds UPS zones from zip code
91	ENVELOPE	Types envelope including return address
92	AUTOEXP	Automobile expense analysis
93	INSFILE	Insurance policy file
94	PAYROLL2	In memory payroll system
95	DILANAL	Dilution analysis
96	LOANAFFD	Loan amount a borrower can afford
97	RENTPRCH	Purchase price for rental property
98	SALELEAS	Sale-leaseback analysis
99	RRCONVBD	Investor's rate of return on convertable bond
100	PORTVAL9	Stock market portfolio storage-valuation program

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Listing 5 continued

```
((EQ(CAR E)(QUOTE FAC))
  (COND((EQ FIRST 1)1)
        ((EQ FIRST 0)1)
        (T(LIST FIRST
              (QUOTE !)))))
(T E)))))))
```

Listing 7: *TWONUM simply checks to see if the variables FIRST and SECOND are numbers. If so, it returns T (for true); otherwise, it returns NIL.*

```
(DEF TWONUM( )
  (COND((NUMBER FIRST)(NUMBER SECOND))))
```

Listing 8: *In listing 8a DERIV provides the thread which ties PREF, INFIX, and DIFF together. The CHR function is analogous to the CHR$ function in BASIC. The sequence (CHR 28)(CHR 31) clears the screen. Listing 8b shows a sample run of the function DERIV. User input is preceded by the prompt, >.*

(8a)

```
(DEF DERIV( )
  (PROG( )
    (CHR 28)
    (CHR 31)
    (PRINT(QUOTE(DERIV "---" A SYMBOLIC DIFFERENTIATOR)))
    (TERPRI)
    (TERPRI)
LOOP(PRIN1(QUOTE >))
    (PRINT(INFIX(DIFF(PREF(READ))(PREF(READ)))))
    (GO LOOP)))
```

(8b)

```
>(DERIV)
(DERIV---A SYMBOLIC DIFFERENTIATOR)
>(A / B)B
((− A)/(B↑2))
>(X * X * X)X
(3 *(X↑2))
>(SIN 2 * X)X
((COS(2 * X))* 2)
>(LOG X)X
(1 / X)
>(X ↑ 4)X
(4 *(X ↑ 3))
>(X↑N)X
(N *(X↑(N − 1)))
```

Input	Output
(DIFF(QUOTE(ADD A A))(QUOTE A))	(ADD 1 1)
(DIFF(QUOTE(TIMES X X))(QUOTE X))	(ADD(TIMES X 1)(TIMES X 1))
(DIFF(QUOTE(LOG X))(QUOTE X))	(TIMES(DIV 1 X)1)
(DIFF(QUOTE(COS X))(QUOTE X))	(TIMES(SUB 0(SIN X))1)
(DIFF(QUOTE A)(QUOTE B))	0
(DIFF(QUOTE B)(QUOTE B))	1

Table 3: *Exemplary input and output of DIFF, which differentiates its first argument with respect to the second.*

Listing 6: *MATCH, an elementary pattern matcher, used by INFIX to simplify algebraic expressions by recognizing such things as the multiplicative and additive identities.*

```
(DEF MATCH(X Y)
  (COND((EQ X(QUOTE ?))T)
       ((AND(ATOM X)(EQ X Y))T)
       ((OR(ATOM X)(ATOM Y))NIL)
       (T(AND(MATCH(CAR X)(CAR Y))
         (MATCH(CDR X)(CDR Y))))))
```

Text continued from page 222:

necessary to translate the output from LISP notation to infix notation. This process is performed by the output parser, INFIX, shown in listing 5. This function generously uses another function, MATCH, shown in listing 6, which was described lucidly by William A Kornfeld in the BYTE LISP theme issue (see reference 3). MATCH receives two arguments and determines whether or not they follow the same pattern. If a question mark, ?, is encountered in the first argument, any atom of the second argument will match it. A few examples of this "wild-card" usage are in order:

```
(MATCH(QUOTE(A B C))
  (QUOTE(A B C))) = T
(MATCH(QUOTE(A B D))
  (QUOTE(A B C))) = NIL
(MATCH(QUOTE(A B ?))
  (QUOTE(A B C))) = T
```

Once patterns are recognized by INFIX, the straightforward parsing operation begins. INFIX is also configured to recognize the multiplicative and additive identities as well as many algebraic simplifications.

The nerve center of INFIX is a PROG function that calls itself recursively on the first and, if necessary, the second argument of the input expression. This, in effect, allows INFIX to get to the bottom of things. The use of the variables FIRST and SECOND prevents INFIX from having to recompute them at every encounter. INFIX uses the function TWONUM (given in listing 7), which determines if both arguments are

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Listing 9: *In listing 9a, the function definition of TAYLOR illustrates the use of PROG as an iterative programming mechanism. Listing 9b shows a sample run of the function TAYLOR. The > prompt precedes user input. The output consists of a list of the terms of the generated Taylor series. The resulting series is obtained by summing the terms. User input consists of the function to be expanded, the value about which the expansion is to occur, and the number of terms desired.*

(9a)

```
(DFF TAYLOR( )
  (PROG( )
    (CHR 28)
    (CHR 31)
    (PRINT(QUOTE(TAYLOR "---" A TAYLOR SERIES GENERATOR)))
    (TERPRI)
    (TERPRI)
LOOP(PRIN1(QUOTE >))
    (TS(PREF(READ))(READ)(READ)(READ))
    (GO LOOP)))
```

(9b)

```
>(TAYLOR)
(TAYLOR---A TAYLOR SERIES GENERATOR)
>(EXP X)X 0 5
1
X
((X↑2)/(2 !))
((X↑3)/(3 !))
((X↑4)/(4 !))
END
>(SIN X)X 0 6
0
X
0
((-1 *(X↑3))/(3!))
0
((X↑5)/(5 !))
END
>(1 / X)X 1 3
1
(-1 *(X - 1))
((2 *((X - 1)↑2))/(2 !))
END
```

Listing 10: *The function definition of TS, the workhorse of the Taylor-series routine. The second argument of EVAL in the function definition illustrates how the programmer can specify the environment by building an appropriate A-list.*

```
(DEF TS(E X A J)
  (PROG(N)
    (SETQ N 0)
LOOP(PRINT(INFIX(LIST(QUOTE DIV)
                (LIST(QUOTE TIMES)
                  (EVAL E(LIST(CONS(QUOTE X)A)))
                  (LIST(QUOTE EXPT)
                    (LIST(QUOTE SUB)
                      X
                      A)
                  N))
                (LIST(QUOTE FAC)
                  N))))
    (SETQ N(ADD N 1))
    (COND((EQ N J)(RETURN(PRINT(QUOTE END)))))
    (SETQ E(PREF(INFIX(DIFF E X))))
    (GO LOOP)))
```

numbers. If so (EVAL E NIL) is executed, which allows INFIX to actually evaluate the expression. Note that the specified A-list is NIL, since no variable bindings (assignments) are required by EVAL.

Tying the Knot

Now that the actors of the differentiation are cast, it is necessary to develop a plot by which they can perform. The function DERIV, shown in listing 8a, serves this purpose. It requires no arguments and begins its duty with housekeeping chores such as clearing the screen and printing a title. It then prints the INFIX of the DIFF of the PREF of READ, or, more simply stated, it prints the derivative of an expression input by the user in infix notation. Upon completion, the process is repeated ad infinitum. A sample run of DERIV is given in listing 8b.

Taylor-Series Expansion

Any standard college calculus textbook (such as reference 5) will tell us that the Taylor series is:

$$f(x) = \sum_{n=0}^{\infty} \frac{f^{(n)}(a)(x-a)^n}{n!}$$

where a is the value about which the expansion is to be taken (noting that if a is 0 the Taylor series reduces to the Maclaurin series), x is the variable of the original function, and n is an integer such that $0 \leq n < \infty$.

It is a relatively simple undertaking to write a Taylor-series program utilizing PREF, DIFF, and INFIX, as indicated by listings 9a and 10. The Taylor function is entered when you type (TAYLOR). It then awaits your input, which consists of:

1. function to be expanded
2. variable about which to expand
3. value about which expansion is to occur
4. number of terms desired

An example of a typical Taylor run is presented in listing 9b.

Final Remarks

The programs in this article demonstrate the ease with which

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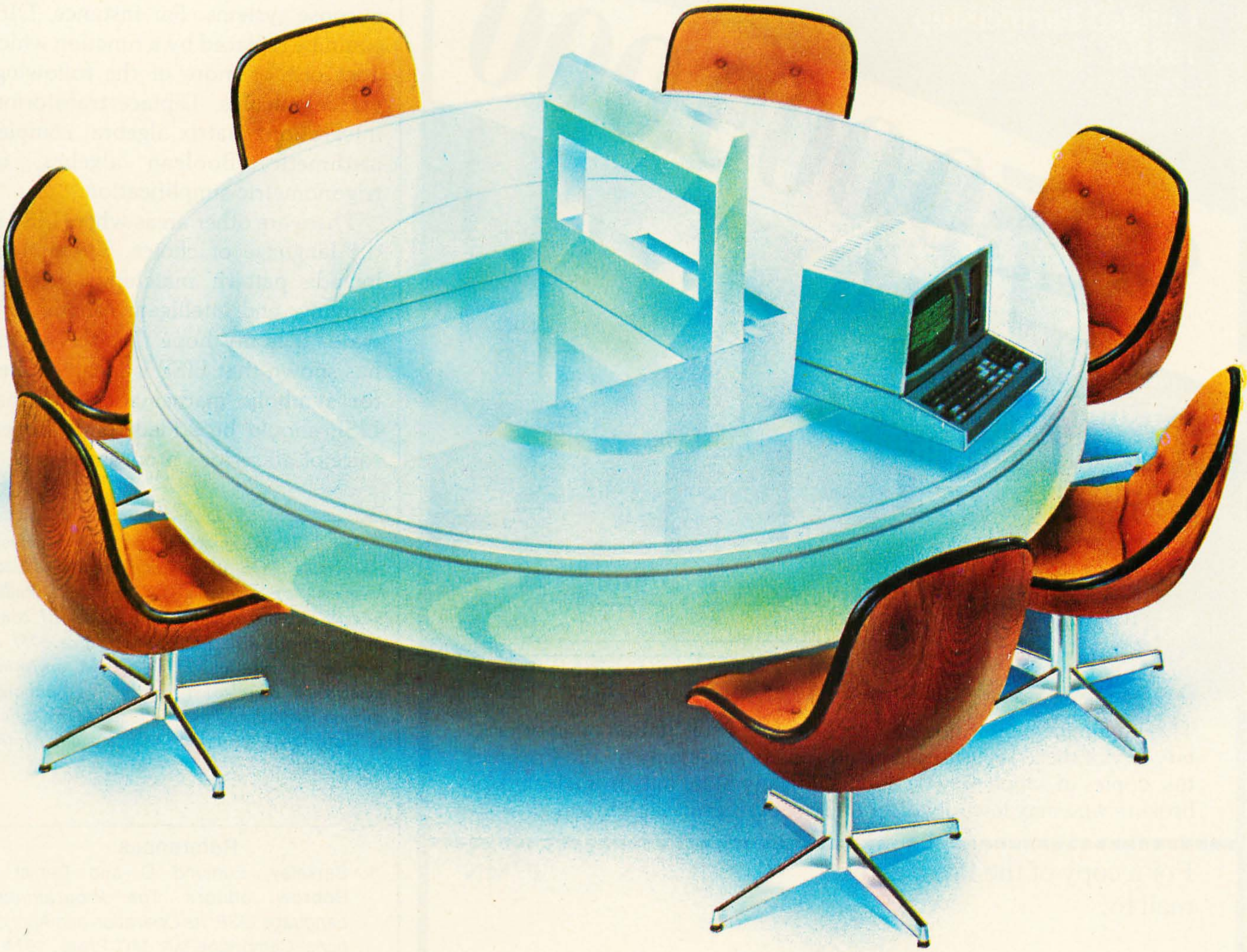

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symbolic mathematics can be expressed in LISP. When viewed within the LISP environment, recursive concepts become clear and concise. By substituting different functional modules for the DIFF function in the aforementioned treatment, you can easily develop powerful special-purpose systems. For instance, DIFF could be replaced by a function which does one or more of the following: vector calculus, Laplace transforms, integration, matrix algebra, complex arithmetic, Boolean algebra, or trigonometric simplification.

There are other areas where LISP is the language of choice. These areas include pattern matching, theorem proving, and intelligent robotic software. It is my hope that this article has shown that LISP is ideally suited for symbolic mathematics and that LISP should be added to the repertoire of all serious programmers.■

The LISP interpreter is sold by Supersoft Associates, POB 1628, Champaign IL 61820. Versions are available for 16 K-byte Radio Shack TRS-80 Model I and Model III computers (floppy disk, $100; cassette tape, $75). A version to run under the CP/M operating system will be released shortly. The symbolic-differentiation program discussed in this article is distributed with the disk versions of the interpreter.

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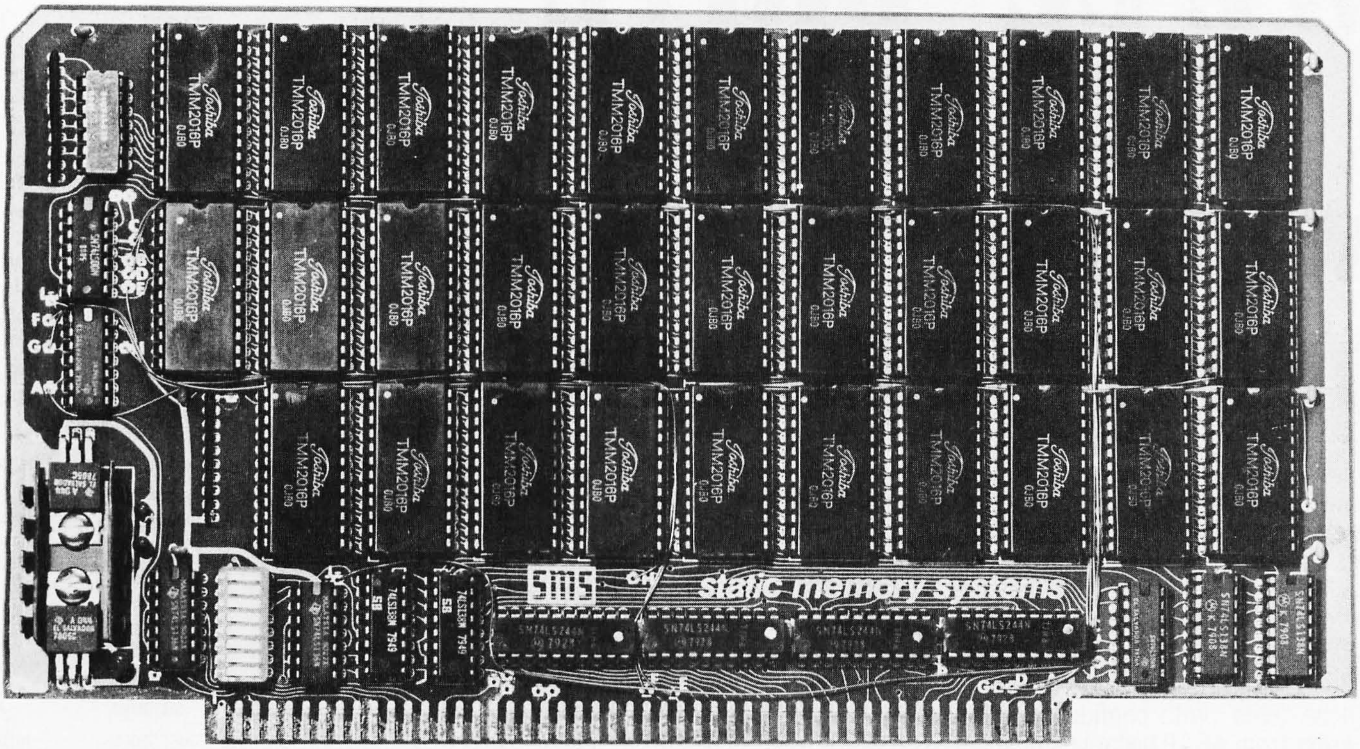
THE LAST MEMORY



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Knowledge-Based Expert Systems Come of Age

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Question: What do the following tasks have in common? Diagnosing bacterial infections; choosing a good spot on a mountain to drill for molybdenum; configuring the many components that make up a DEC VAX-11 computer; determining the structure of a complex molecule from mass spectrogram data.

Answer: They are important and difficult decision-making jobs that only a few experts do well. The reasoning process in each job includes use of judgment, rules of thumb, and experience. Furthermore, these jobs can all be done today by computer programs known as *knowledge-based expert systems*.

What makes knowledge-based expert systems different from other large computer programs written to solve special decision-making problems? We will answer that question in this article and explain how expert systems work. We will briefly describe several existing expert systems, and show the operation of one—a mineral-exploration program we helped develop. As a bonus, we will provide a micro expert-system in BASIC for your personal computer.

Since work on expert systems grew out of research on AI (artificial intelligence), a few historical observations will provide some perspective. As is clear from this special issue of BYTE, AI is concerned with making computers perceive, reason, and understand. Early work in AI looked for simple and powerful reasoning techniques that could be applied to many different problems. A classic example is the work of Newell, Shaw, and Simon on a program called GPS (see reference 21). Intended to be a general problem solver, GPS could prove theorems and solve puzzles and a wide variety of logical problems. Thus, the generality of its particular reasoning technique—called means-ends analysis—was convincingly demonstrated.

IF-THEN rules are used to capture the kind of "semilogical" response to familiar patterns that characterizes much of everyday human thinking.

Unfortunately, attempts to apply such general methods to larger and messier real-world problems were mostly unsuccessful. The methods were not wrong, they were just insufficient. They did not address the difficulties of reshaping a problem into a form the programs could work on. Nor could these general methods, by themselves, cope with the enormous search spaces of alternatives.

How do *people* cope with these same problems? One answer is that people know much more than computers. People rarely solve problems by reasoning everything out from the first principles. While recreational puzzles can often be solved by strict logical deduction, many real-world problems seem to be solved by "semilogical" methods, such as recognizing one of a thousand familiar patterns applying to the current situation and recalling the appropriate thing to do when that pat-

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tern occurs. In everyday affairs, logical deduction is an adjunct to other mental processes.

Recognizing that knowledge is as important as reasoning, AI researchers have worked on a variety of methods for representing and using knowledge. They have also grappled with fuzzier kinds of problems, where logic is supplemented by hunches based on experience and judgment. One result has been the development of several knowledge-based expert systems—programs that exploit special knowledge to solve difficult problems in specialized areas. These programs include the DENDRAL program for mass-spectrum analysis (see reference 14), the MYCIN program (reference 27) and several others (references 18 and 25) for medical diagnosis, the PROSPECTOR program for mineral exploration (reference 11), and the R1 program for configuring VAX computer systems (reference 20).

Representing Knowledge in Rules

How do you represent the knowledge needed to do these kinds of tasks? That is still a matter of debate and active research in AI circles. One popular approach is to use IF-THEN rules (also called situation-action rules or production rules). These rules say that if a certain kind of situation arises, a certain kind of action can be taken. They are typically used to capture the kind of "semilogical" response to familiar

1a

The R1 system (configuring VAX systems):

IF: (1) The current context is assigning devices to Unibus modules, and
(2) There is an unassigned dual-port disk drive, and
(3) The type of controller it requires is known, and
(4) There are two such controllers, neither of which has any devices assigned to it, and
(5) The number of devices that these controllers can support is known

THEN: (1) Assign the disk drive to each of the controllers, and
(2) Note that the two controllers have been associated and that each supports one device.

1b

The MYCIN system (medical diagnosis):

IF: (1) The site of the culture is blood, and
(2) The identity of the organism is not known with certainty, and
(3) The stain of the organism is gramneg, and
(4) The morphology of the organism is rod, and
(5) The patient has been seriously burned

THEN: There is weakly suggestive evidence (0.4) that the identity of the organism is pseudomonas.

1c

The PROSPECTOR system (mineral exploration):

IF: There is hornblende pervasively altered to biotite

THEN: There is strong evidence (320, 0.001) for potassic zone alteration.

Table 1: *Sample IF-THEN rules from three knowledge-based expert systems. Table 1a shows a rule that the R1 system uses to configure DEC's VAX systems. Table 1b shows a rule that the MYCIN system uses to perform medical diagnosis. The number 0.4 indicates the degree to which the conclusion follows from the evidence on a scale of 0 to 1. Table 1c shows a rule used by PROSPECTOR in mineral exploration. The number 320 indicates how sufficient the evidence is for establishing the hypothesis if the evidence is, in fact, present; the number 0.001 indicates the degree to which the absence of this evidence will rule out the hypothesis. Both these numbers are multipliers. Values greater than 1 increase the likelihood of the sufficiency or necessity of the evidence for establishing the hypothesis, and values less than 1 decrease the likelihood.*

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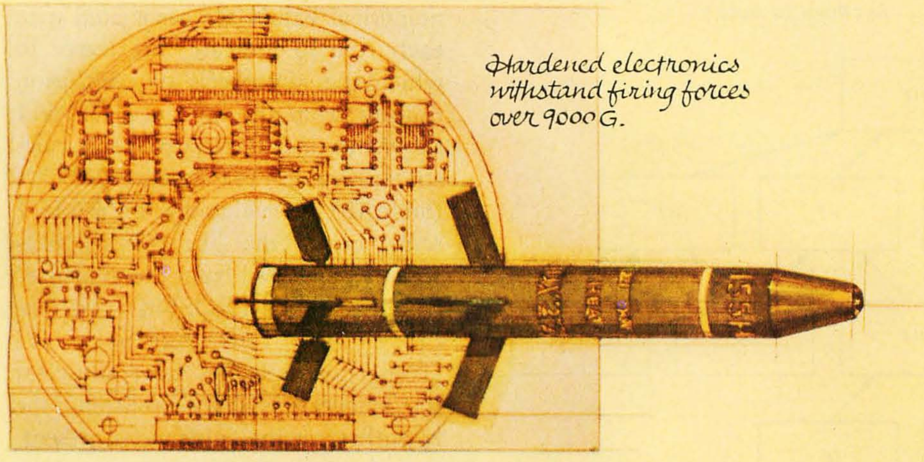

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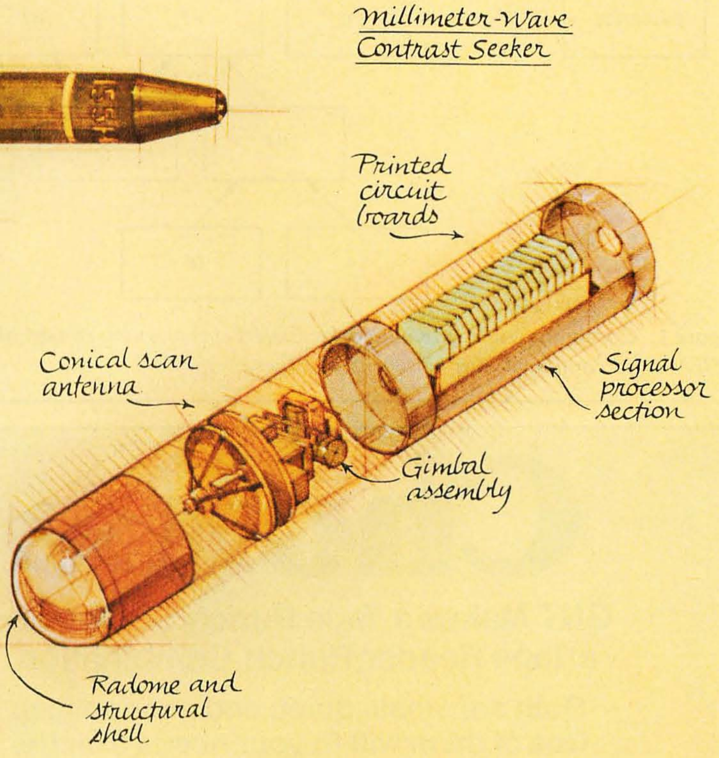

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patterns that characterizes much of everyday human thinking. Table 1 lists examples of rules from several rule-based systems.

In general, rules like these represent a "chunk" of knowledge about a particular field. Most existing rule-based systems contain hundreds of rules, usually obtained by interviewing experts for weeks or months. For example, the MYCIN system contains about 450 rules; the R1 system has about 800, and the PROSPECTOR system has about 1600. In any system, the rules become connected to each other to form rule networks.

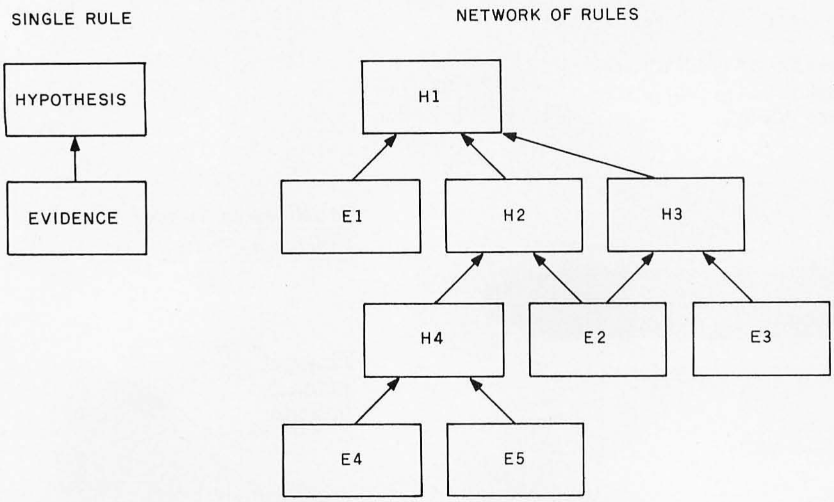

Figure 1: *Combining rules into networks. Expert systems may consist of hundreds of IF-THEN rules combined into networks like these.*

Once assembled, such networks can represent a substantial body of knowledge. Figure 1 illustrates how rules are combined together into networks.

An expert usually has many judgmental or empirical rules according to which the evidence supports a conclusion or hypothesis, but with less than absolute certainty. In these cases, numerical values are associated with each rule to indicate the degree to which the hypothesis or conclusion follows from the evidence. Table 1 shows two examples of such rule-strength values: in the case of MYCIN (table 1b), the value 0.4 (on a 0 to 1 scale) means that the conclusion is weakly suggested from the evidence. In the case of PROSPECTOR (see table 1c), two numbers are given—one indicates how sufficient the evidence is for establishing the hypothesis if the evidence is present, the other indicates the necessity of the evidence for the hypothesis, ie: the degree to which the absence of that evidence will rule out or "kill" the hypothesis. (There is more about the meaning of these numbers in the later section on PROSPECTOR.)

The rules are not implemented as subroutines or in any other part of the code of the program. Instead, the rules for a particular task are written in a specialized language, which is then input by the program to produce an internal representation that makes the expert system an expert about that task domain. The program itself is only an interpreter and a general-reasoning mechanism. This illustrates an important distinction between rule-based systems and more conventional computer programs: there is a clear separation of general knowledge about the problem (the rules forming a knowledge base) from information about the current problem (the input data) and methods for applying the general knowledge to the problem (the rule interpreter). Figure 2 illustrates this contrast. (Lines 3880 through 4040 of listing 1 give a set of rules input to that program.)

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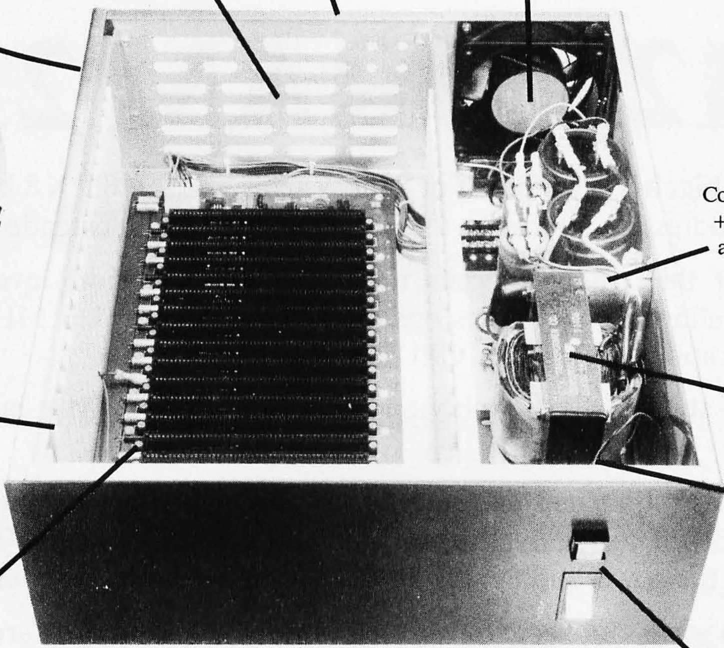

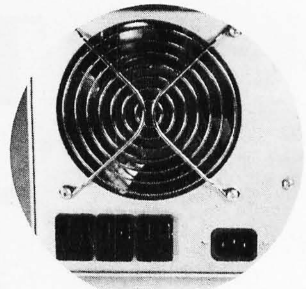

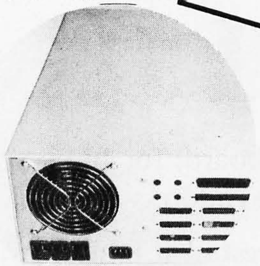

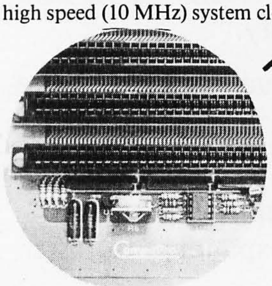

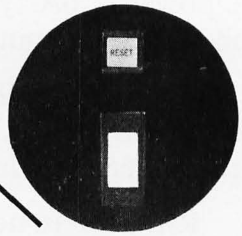

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coded as rules, how can it be put to use? This question has more than one answer. One general approach is the use of a *production system* (see reference 10). A production system contains three major components—a *set of rules*, a *global data base*, and a *rule interpreter*. Some people call the set of rules the *knowledge base* and the rule interpreter the *inference system*. McDermott calls the global data base the working memory, using the term "data base" for a file of needed facts (see reference 20). Despite this variety of terminology, the basic ideas are the same. The rules have the following general form:

IF: $<\text{antecedent}_1>$
.
.
.
$<\text{antecedent}_m>$
THEN: $<\text{consequent}_1>$
with certainty C_1
.
.
.
$<\text{consequent}_n>$
with certainty C_n

The antecedents can be thought of as patterns that can be matched against entries in the data base, and the consequents as actions that can be performed (or conclusions that can be deduced) if all the antecedents match. In the case of the R1 example (see table 1a), the data base would contain assertions about such things as what the current context is, and whether or not there is an unassigned dual-port disk drive. The consequent actions can cause changes to the contents of the global data base, by changing an assertion about the status of the assignment of devices to a controller, or by asking the user a question and adding the answer given to the data base. Thus, the application of a rule can change the state of the data base, enabling some rules and disabling others.

Control Strategies

How are the enabled rules found, and what decides which rules to apply? This is the job of the rule interpreter, and the strategy it follows is called the *control strategy*.

One of the simplest strategies is to scan through the rules until one is found whose antecedents match assertions in the data base. The rule is applied, updating the data base, and the scanning resumes. This process continues until either a goal state is reached or no applicable rules are found. R1 uses a variant of this basic procedure. Since the behavior of the system is directly responsive to the facts about the problem entered in the global base, this is known as a *data-driven* control strategy. This strategy is also known as *forward-chaining* or *antecedent reasoning*.

We think of each rule as a subroutine. Instead of being called by name, a production-system subroutine is triggered by the appearance of certain patterns in the data base. Anathema to lovers of structured programming, such pattern-directed systems have long fascinated AI researchers (see reference 32). In particular, the use of such systems as psychological models was pioneered by Newell and Simon (reference 22) in the development of GPS.

A different strategy is to select a goal to be achieved and scan the rules to find those whose consequent actions can achieve the goal. Each such rule is tried in turn. If the antecedents for a rule match existing facts in the data base, the rule is applied and the problem solved. If an unmatched antecedent is encountered, arranging conditions to match that antecedent becomes a new subgoal, and the same procedure is applied recursively. If there are no rules to establish the new subgoal, the program asks the user for the necessary facts and enters them in the data base. Since the behavior of the system is directly responsive to the goals the system is trying to achieve, this is known as a *goal-driven* control strategy. (This strategy is also known as *backward-chaining* or *consequent reasoning*, and is closely related to means-end analysis.) A variant of a goal-driven control strategy is used successfully by MYCIN and is the method used in the micro expert-system described in the last section of this article. (It is possible to use other control strategies that combine elements of data-driven and goal-driven policies, as we did in our work on PROSPECTOR. See reference 11.)

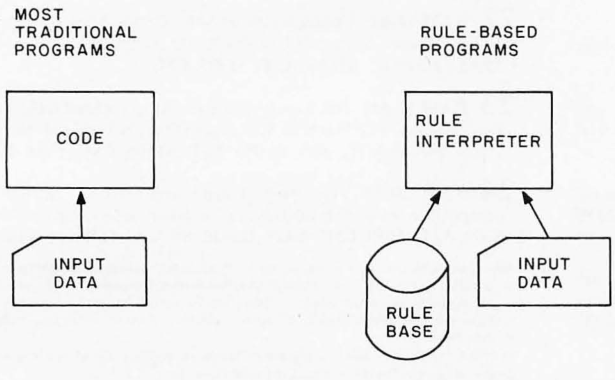

Figure 2: *Contrast between traditional programs and rule-based programs. A rule-based program is divided into a general-reasoning program, called the rule interpreter, and a file of judgmental rules obtained from an expert, called the rule base or knowledge base. The rule interpreter loads the rule base into an internal representation and uses the rule base to guide an interactive consultation with the user.*

System Characteristics

We can now see more clearly how rule-based expert systems differ from more conventional computer programs. As mentioned earlier, one major difference is the separation of the expert knowledge (the rules forming a knowledge base) from the general-reasoning mechanism (the rule interpreter). This partitioning, together with the further division of general knowledge into many separate rules, offers several important advantages:

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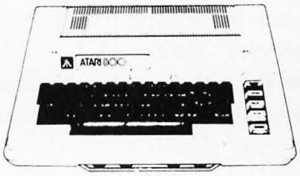

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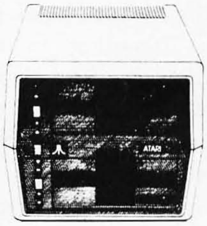

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knowledge base over an extended time by letting the developers refine old rules and add new ones
- the same general system can be used for a variety of applications, essentially by "unplugging" one set of rules and "plugging" in another
- the same knowledge can be put to use in different ways (including teaching) by changing the rule interpreter
- the program can give simple and illuminating explanations of its behavior merely by describing the rules it is applying (this also turns out to be a powerful way to debug faulty rules)
- the possibility of developing systems that are introspective (eg: can check the consistency of their own rules) and evolutionary (eg: can modify their own rules and learn new ones)

All these advantages are present in a rudimentary but interesting way in the micro expert-system described at the end of this article.

Another characteristic of most expert systems is that they try to mimic, at least to some extent, the way human experts make decisions. The "spot-a-pattern/draw-a-conclusion" style of reasoning is used as much by experts on special problems as it is by all of us on day-to-day problems; what distinguishes the expert from the rest of us is the expert's unusual and valuable set of rules. Such rules are often not conclusive, but only suggestive of the conclusion. For example, if a car won't start and the headlights are dim, the battery is probably bad, but there are other possibilities. To mimic experts, then, a rule-based system should let the expert state the degree of significance or certainty that should be attached to the conclusion of a rule.

A Sampling of Expert Systems

To understand both the capabilities and limitations of knowledge-based systems, it is helpful to examine specific systems created to solve particular problems. At first glance, their only common characteristic seems to be their reliance on explicitly encoded knowledge. Groupings based on the method of knowledge representation (eg: production rules) or on the domain of application (eg: medicine) reveal little additional commonality.

However, we can gain some insight by grouping the systems according to their general function. Table 2 shows a classification of well-known knowledge-based systems into eight general categories. We will now define most of these categories and describe some representative programs.

Function	Domain	System	Reference
Diagnosis	Medicine	PIP	24
	Medicine	CASNET	34
	Medicine	INTERNIST	25
	Medicine	MYCIN	27
	Medicine	PUFF	13
	Engineering	SACON	3
	Geology	PROSPECTOR	11
Search	Chemistry	DENDRAL	14
	Chemistry	SECHS	36
	Chemistry	SYNCHEM	16
Problem Solving and Planning	Circuit analysis	EL	28
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	Medicine	GUIDON	8
Knowledge Acquisition	Diagnosis	TEIRESIAS	9
	Diagnosis	EMYCIN	30
	Diagnosis	EXPERT	33
	Diagnosis	KAS	26
System Building	—	ROSIE	31
	—	AGE	23
	—	HEARSAY III	1

Table 2: *A classification of existing knowledge-based systems by function. Numbers at the right indicate references about each system (given at the end of the article).*

Diagnosis Problems

The general diagnosis problem is one of classifying an object, event, or situation on the basis of perhaps uncertain information about its characteristics. The categories may or may not be mutually exclusive, and the data can be acquired sequentially or in parallel. In a formal sense, diagnosis problems can always be posed as problems in statistical-decision theory, whose solution usually requires the estimation of a multivariate probability function from vast amounts of data. The knowledge-based-systems approach to such problems effectively substitutes the knowledge and judgment of expert humans for this unknown function.

Several impressive knowledge-based systems have been developed for medical-diagnosis problems. The INTERNIST program developed by Pople and Myers at the University of Pittsburgh uses information from 4000 possible manifestations to diagnose problems of internal medicine that can involve multiple instances of 500 different disease types (see reference 25). The program contains a large taxonomy of disease types, together with rules that link manifestations to these types, as well as an ingenious control procedure for narrowing down the disease classes that explain the manifestations. In many tests, INTERNIST has demonstrated the capability of correctly diagnosing multiple-disease cases described in medical journals as being particularly difficult.

Another well-known medical-diagnosis program is the MYCIN system developed by Shortliffe and his colleagues at Stanford (see reference 27). MYCIN is a consulta-

Text continued on page 254

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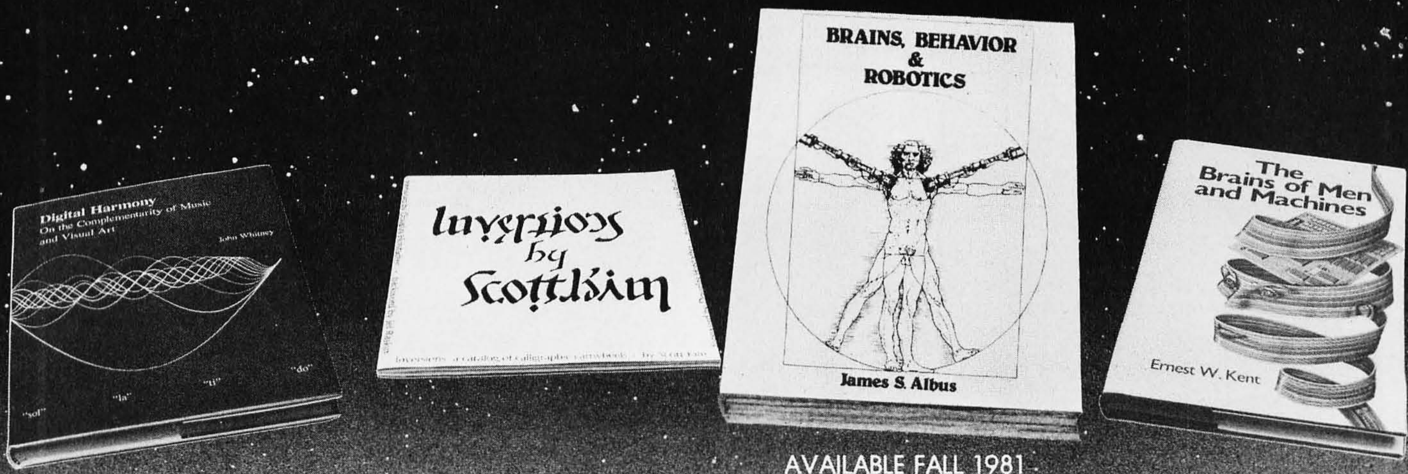

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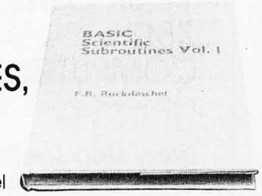

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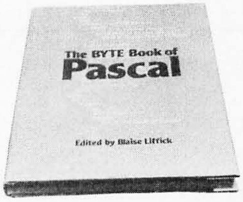

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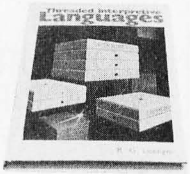

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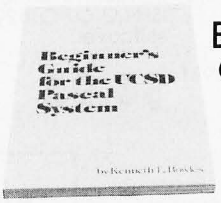

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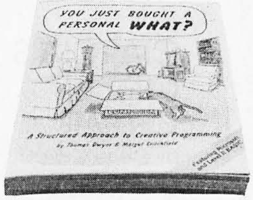

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Text continued from page 248:

tion designed to diagnose bacterial infections and recommend antibiotic therapy. MYCIN is organized around the systematic use of a large collection of rules that link patient data to infection hypotheses. Formulas based on a probability-like theory of certainty are used to accommodate the inexact nature of the relevant medical knowledge. In several ways, the program exploits the modularity provided by the use of rules to express this medical knowledge. From a system-development standpoint, modularity allows long-term incremental development of the system by continual expansion and refinement of the rule base. The program obtains information from a user by simply chaining backward through the rules. This lets the program furnish simple but useful explanations of its reasoning by stating the rules it is using.

Search

Many problems in graph theory, game theory, and other areas of discrete mathematics can be posed as search problems. These problems are characterized by the existence (at least in principle) of a systematic method for generating candidate solutions, as well as a systematic method for testing acceptability. As regards genuinely interesting problems, the number of candidate solutions is usually so great that an exhaustive search is infeasible. Any device that significantly reduces the amount of search required (preferably without compromising the quality of the solution) is called a *heuristic*, and a search strategy guided by heuristics is called *heuristic search*.

Since the study of heuristic search was one of the earliest activities in AI, it is natural that DENDRAL—one of the first knowledge-based systems—was concerned with using knowledge to limit search (see reference 14). Begun in 1965 by Feigenbaum, Lederberg, and their colleagues at Stanford University, DENDRAL generates plausible structural representations of organic molecules from mass-spectrogram data, nuclear-magnetic-resonance data, and additional constraints provided by the user. The program runs in a plan-generate-test sequence: (1) deriving necessary constraints on the molecular structure, (2) systematically generating structures that satisfy those constraints, and (3) testing the proposed structures by predicting the mass spectrogram and rejecting those that disagree with the experimental results. The knowledge needed for step 2 is encoded as an ingenious special procedure. The knowledge needed for steps 1 and 3 is encoded as tables of production rules, a method compatible with the way chemists think about the rules of mass spectrometry (see reference 5).

For the molecular families covered by these empirical rules, the program is said to surpass even expert chemists in speed and accuracy. The results obtained with it have been published in many papers in chemistry journals (see reference 13).

Problem Solving and Planning

An important class of logical problems concerns dividing a problem into a set of simpler subproblems. To be useful, a solution must be con-

structive; it usually consists of a sequence of actions that will achieve some goal. Examples of such problems are theorem proving, program synthesis, and robot planning.

EL is a knowledge-based system for the steady-state analysis of resistor-diode-transistor circuits (see reference 28). It uses production rules to represent general principles, such as Kirchhoff's laws and Ohm's law, as well as the characteristics of types of devices. Facts about the circuit being analyzed are represented as assertions in an associative data base. The rule interpreter is written in a special language called ARS (antecedent-reasoning system). As its name implies, ARS supports the use of rules in the antecedent mode, in which the factual assertions trigger the rules. The actions of the rules create new assertions, which in turn trigger additional rules.

An important property of ARS is the ability to make conjectures when no additional direct deductions are possible, and to keep track of those conjectures and any conclusions dependent upon them should subsequently detected contradictions require their revision. This ability allows the analysis of a circuit to proceed when the conducting or nonconducting states of its nonlinear devices are unclear. It also permits the user to modify the circuit and see the effects of changes without having to reanalyze the entire circuit. ARS can employ the same facilities to provide explanations of its reasoning.

Computer-Aided Instruction

Three types of traditional CAI (computer-aided instruction) are often distinguished: frame-oriented drill-and-practice programs (which are unrelated to what AI people call frame-based representations); games and simulations (usually used to teach diagnosis), and exploratory systems that allow the student to experiment freely and learn by doing. Among the limitations of these programs are their inability to conduct dialogues with the student in natural language, to respond to unanticipated responses, to diagnose the student's errors, or to improve with experience. The potential applicability of artificial-intelligence techniques to solving these problems was outlined by Carbonell ten years ago (see reference 7), and a variety of approaches have subsequently been explored. To the extent that knowledge of the subject matter is required for a solution, knowledge-based systems have an obvious contribution to make to CAI.

The GUIDON system developed by Clancey at Stanford exploits the MYCIN knowledge base about meningitis and bacteremia to teach both facts and problem-solving strategies (see reference 8). MYCIN's 450 diagnostic rules were not modified, but were augmented by an additional 200 rules that included methods for guiding the dialogue with the student, presenting diagnostic strategies, constructing a student model, and responding to the student's initiative. By replacing MYCIN's rules by a separate set of MYCIN-style rules used in the PUFF program for diagnosing pulmonary disease, Clancey was able to use GUIDON to tutor students about pulmonary-function analysis. Thus, GUIDON

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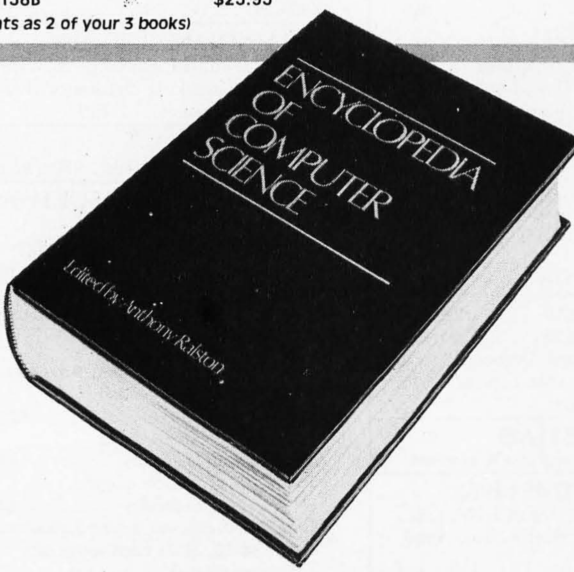

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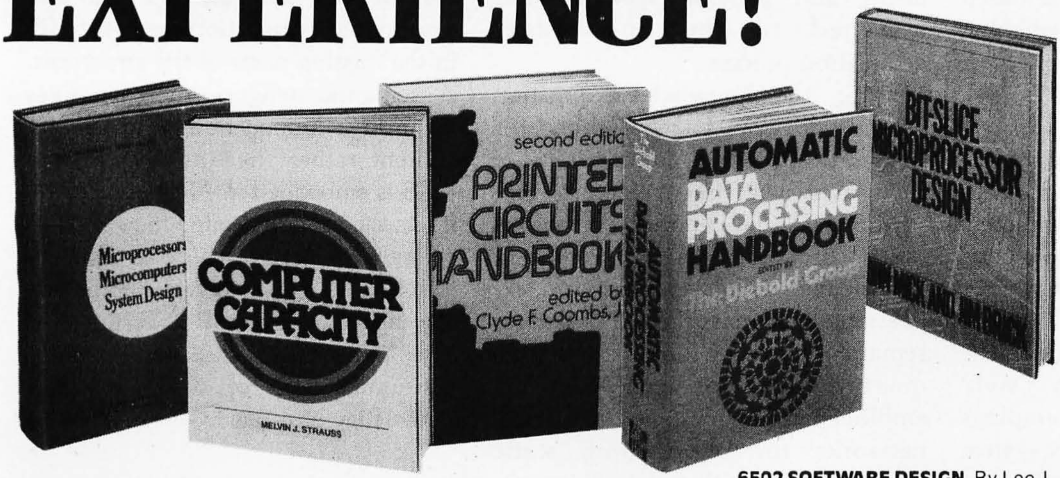

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has shown that a knowledge-based system can be exploited for teaching about its knowledge base.

Knowledge Acquisition

As an alternative between the extremes of complete handcrafting of the knowledge base and completely automated learning, researchers have investigated the development of various tools that can facilitate the process of acquiring knowledge. The most ambitious of these is Davis' TEIRESIAS system that employs knowledge about the MYCIN system to supervise interaction with an expert in building or augmenting a MYCIN rule set (see reference 9).

Giving the expert direct access to the program is an appropriate ultimate goal. But the expert usually lacks sufficient understanding of the program's representational mechanisms to appreciate the consequences of the many choices the program offers. An alternative to direct access is to use a computer scientist who understands the program's mechanisms and provide specific tools matched to the knowledge-acquisition process.

KAS, the knowledge-acquisition system developed by Reboh for PROSPECTOR, is an example of such a system (see reference 26). PROSPECTOR employs various kinds of networks to represent knowledge—rule networks for expressing judgmental knowledge, semantic networks for expressing the meaning of the propositions employed in the rules, and taxonomic networks for representing static knowledge about the relations among terms in the domain. The core of KAS is a network editor. The editor's basic operations allow it to create, modify, or delete various kinds of nodes and arcs. The network editor knows about the various mechanisms employed by PROSPECTOR, protects the user against certain kinds of syntactic errors, and includes a system that keeps track of partial constructs that remain to be completed. At any time, the user can turn control over to KAS, and KAS will systematically question the user to fill in the missing parts of the structures. A semantic network matcher gives the user a limited ability to edit by content rather than by form. Since KAS is embedded in PROSPECTOR, it lets the user determine the effects of changes by permitting controlled execution of the program. Although specialized to PROSPECTOR, KAS gives powerful assistance in the time-consuming task of developing the knowledge base.

System Building

Many knowledge-based systems that have been built—especially in the area of diagnosis—have generally similar structures. In particular, all rule-based systems have a *rule interpreter*, a collection of rules making up the knowledge base, and a global data base of assertions about the particular case being diagnosed. Several researchers have illustrated the generality of their systems by showing that they can be applied to another domain merely by removing the rules for a given domain and substituting rules for the new one (see references 17 and 30).

Every domain, however, has its own peculiarities. Despite the good intentions of system builders, these peculiarities inevitably influence the design of a system. As a result, a serious attempt to build a new knowledge-based system almost always requires changes in all parts of the system. Recognizing these facts, researchers have recently begun developing what amount to programming languages for building expert systems. While these languages are just coming into use and are certain to undergo further development, they promise to reduce significantly the programming effort needed to develop a new system.

AGE is a good example of the most recent efforts in this direction (see reference 23). Specifically designed to allow the implementation of a broad spectrum of knowledge-based systems, AGE gives the designer a set of separate, interconnectable, preprogrammed modules for im-

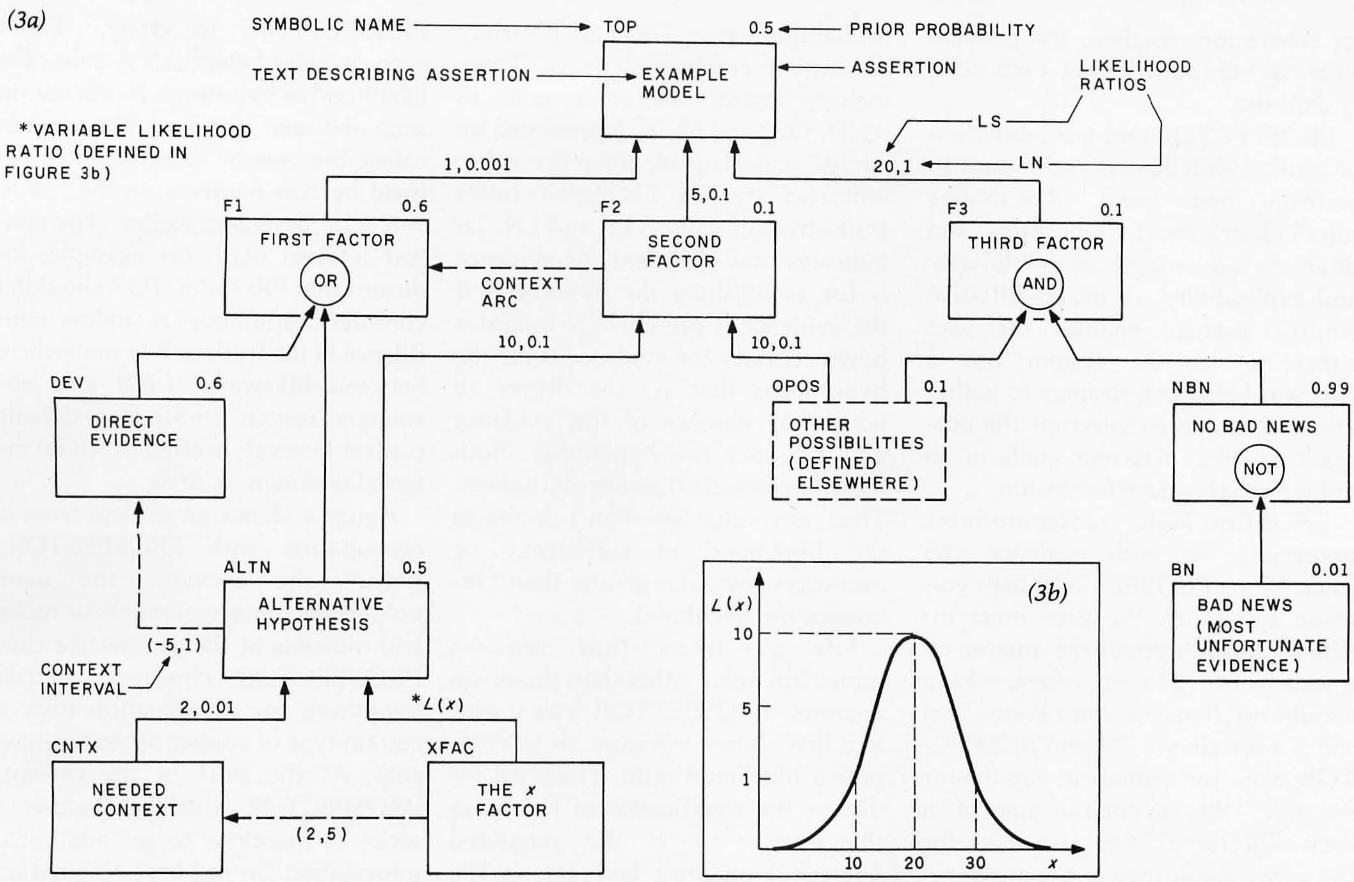

Figure 3: *Diagram showing some of the constructs used in the PROSPECTOR inference networks. In figure 3a, boxes represent assertions. Each assertion's symbolic name is at the upper-left corner of the box and text describing the assertion is inside the box. Most assertions have prior probability values shown at the upper-right corner of the box. Evidence can be combined by logical connectives such as AND, OR, and NOT, represented by circles inside boxes; by plausible inference rules, indicated by two rule-strength values, LS and LN (LS indicates how sufficient the evidence is for establishing the hypothesis, if the evidence is present; LN indicates how necessary the evidence is for the hypothesis), and by variable likelihood ratios [L(x)], defined in figure 3b. Dashed arrows indicate contextual constraints, which can "turn on or off" one question or a whole section of the network (at the tail of the arrow), depending on the answer to another question (at the head of the arrow). Figure 3b shows a plot defining a likelihood ratio L(x) for a numerical answer x to a question from PROSPECTOR. The likelihood ratio depends on the numerical value provided by the user.*

plementing the knowledge base, the interpreter, and the data base. It also provides ways to escape to the host programming language to implement arbitrary procedures. The knowledge base can be represented either as sets of production rules or as frame systems (called units), or the two representations can be combined. For the interpreter, AGE supplies standard procedures for forward-chaining and backward-chaining, plus convenient ways to implement other strategies. The standard global data base is a so-called blackboard system (see reference 19). AGE also contains knowledge about its own facilities and procedures, and a tutor subsystem that lets the user browse in this on-line manual. A design subsystem provides on-line advice on the use of AGE itself.

The design of any programming language always involves a compromise among convenience, generality, and efficiency (in time or space). Clearly, systems like AGE, ROSIE, HEARSAY III, and RLL, are attempts to gain convenience, generality, and design-time efficiency for relatively modest additional cost in space and run-time efficiency. While there is not yet enough experience with such systems to assess their value, we expect them to play a significant role in future developments.

PROSPECTOR: Sample System

Supported by the US Geological Survey and the National Science Foundation, we developed the PROSPECTOR system for mineral exploration (see reference 11). PROSPECTOR contains rule-based models of different kinds of ore deposits. We developed each model by interviewing a geologist who is an authority on a particular class of deposits, and then translating the geologist's knowledge of the associations between field-observable evidence and relevant geological hypotheses into a structured collection of rules. PROSPECTOR models can perform these tasks: (1) evaluate the favorableness of a geologic district for a kind of ore, (2) evaluate the favorableness of a particular exploration site within a district, and (3) evaluate the favorableness of different drilling sites on an exploration site. In addition, PROSPECTOR can suggest which data are most valuable for further exploration, give the rationale

for conclusions reached, and provide informal education about each class of deposits.

PROSPECTOR uses a combination of artificial-intelligence techniques to perform these tasks. MYCIN-like rules link evidence to hypotheses, and offer the advantages of modularity and explicability. A mixed-initiative control strategy enables the user either to let the system use a backward-chaining strategy to gather information, or to interrupt the program to select different goals or to volunteer relevant information.

PROSPECTOR accommodates uncertainty in both evidence and rules. When PROSPECTOR asks yes-or-no questions, the user must indicate certainty about the answer on a scale from −5 to +5, where −5 is a certain no, 0 means don't know, and +5 is a certain yes. When PROSPECTOR asks for numerical input—for example, the geological age of a rock—PROSPECTOR also asks for the user's confidence in the answer.

Figure 3a illustrates the basic form of a PROSPECTOR inference network. Each box stands for an assertion and has a previously assigned probability value. There are a variety of ways to combine evidence. These include logical operators such as AND, OR, and NOT, represented by circles, and plausible-inference rules, indicated by the likelihood ratios (rule-strength values) LS and LN. LS indicates how sufficient the evidence is for establishing the hypothesis if the evidence is present. LN indicates how necessary the evidence is for the hypothesis; that is, the degree to which the absence of this evidence will rule out the hypothesis. Both these likelihood ratios are multipliers. Thus, any value less than 1 decreases the likelihood of sufficiency or necessity; any value greater than 1 increases the likelihood.

For questions that request numerical input rather than yes-or-no answers, PROSPECTOR uses a plot like that shown in figure 3b to compute a likelihood ratio. The chart indicates the significance of ranges in the answer: x is the requested numerical quantity and $L(x)$ is the likelihood ratio.

PROSPECTOR also uses contextual constraints, shown in figure 3a as dashed arrows. These work by telling PROSPECTOR, in effect, "Don't even consider hypothesis A unless the likelihood of hypothesis B falls within such and such a range." The range is called the context interval. It is defined by two numbers on the −5 to +5 scale described earlier. The context interval (2,5), for example, indicates that PROSPECTOR shouldn't consider hypothesis A unless confidence in the truth of B is somewhere between lukewarm (+2) and absolutely certain (+5). The default context interval, in effect when no interval is shown, is (0,5).

Figure 4 shows an excerpt from a consultation with PROSPECTOR. Before the excerpt, the user volunteered observations about rocks and minerals at the prospective site. PROSPECTOR chose an initial hypothesis for investigation (that a certain type of copper deposit is present). At the start of the excerpt, PROSPECTOR is asking the user a series of questions to get additional information. In response to question 12, the user types "4" to indicate a relatively strong degree of certainty about the answer.

PROSPECTOR can accept a variety of answers to questions. For example, in answer to question 14, the user provides the term "cretaceous" to indicate a numerical range of values. When the user types "WHY" instead of answering question 13, PROSPECTOR prints an explanation of the question's geological significance. By typing "WHY" repeatedly, the user can learn more about the expertise captured in the model. After the explanation, PROSPECTOR repeats question 13 and the consultation goes on.

In response to any question, the user has options to seek clarification, change the course of the questioning, trace the implications of answers given, and so on. The consultation continues until PROSPECTOR has confirmed or rejected the hypothesis under consideration. PROSPECTOR then explains the basis of its conclusions in terms of the rules used.

Tests have shown that evaluations made by PROSPECTOR closely match those made by the geologists

The following questions are intended to establish the nature of the petrotectonic setting. (These questions will not be pursued unless a positive answer is given to the next question.)

12 — To what degree do you believe that the target area is in a continental-margin mobile belt? 4
13 — Do you know the age of the continental-margin mobile belt? WHY

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3. The major belt of 60 to 4 m.y. deposits in the Andes of Argentina, Chile, Peru, Ecuador, and Colombia.

<The explanation continues with additional information>

13 — Do you know the age of the continental-margin mobile belt? YES
14 — What is the age of the continental-margin mobile belt? CRETACEOUS = 65 − 136 MILLION-YEARS
What is your confidence in this estimate? 3

<The consultation continues on with many additional questions.>

Figure 4: *An excerpt from a consultation with PROSPECTOR, which has chosen an initial hypothesis to investigate and is now asking the user for additional relevant information. The numerical answer to question 12 indicates the user's degree of certainty about a fact, using a −5 to +5 scale. If the user types "WHY" instead of answering a question, PROSPECTOR explains the question's geological significance.*

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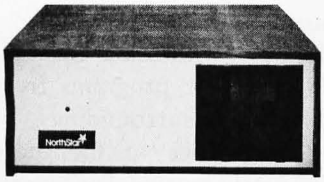

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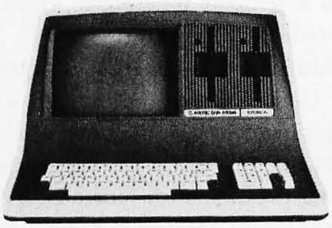

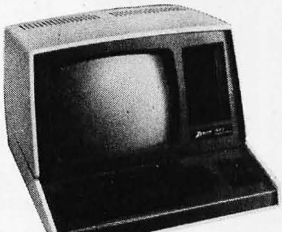

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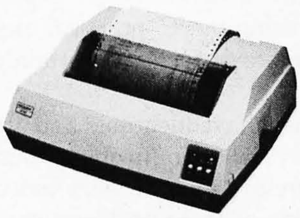

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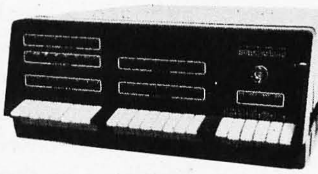

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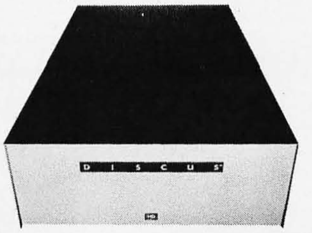

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who created the models; the numerical scores typically agree to within about seven percent on the average (see reference 15).

Appropriate Tasks

While the systems we have described perform a wide variety of tasks, knowledge-based expert systems are more successful in handling some tasks than others. In general, the following are prerequisites for the success of a knowledge-based expert system:

- there must be at least one human expert acknowledged to perform the task well
- the primary source of the expert's exceptional performance must be special knowledge, judgment, and experience
- the expert must be able to explain the special knowledge and experience and the methods used to apply them to particular problems
- the task must have a well-bounded domain of application

Many scientific and technical tasks meet these conditions, especially where there is a tradition of consultation. Certain kinds of tasks are not good subjects for knowledge-based expert systems. For example, although a mathematician possesses specialized knowledge, the additional knowledge needed to function in that role is far more extensive than current knowledge-based expert systems can handle. On the other hand, where there are well-defined mathematical procedures for solving a problem, knowledge-based expert systems are unnecessary. For most perceptual problems, experts are unusual, relevant knowledge is extensive but difficult to pinpoint, and general understanding of the perceptual process is limited. And many tasks are still waiting for the first expert to appear. An example is earthquake prediction. There are now no geologists who can predict earthquakes accurately. An expert system for earthquake prediction should not be expected to fare any better than the human sources of its knowledge base.

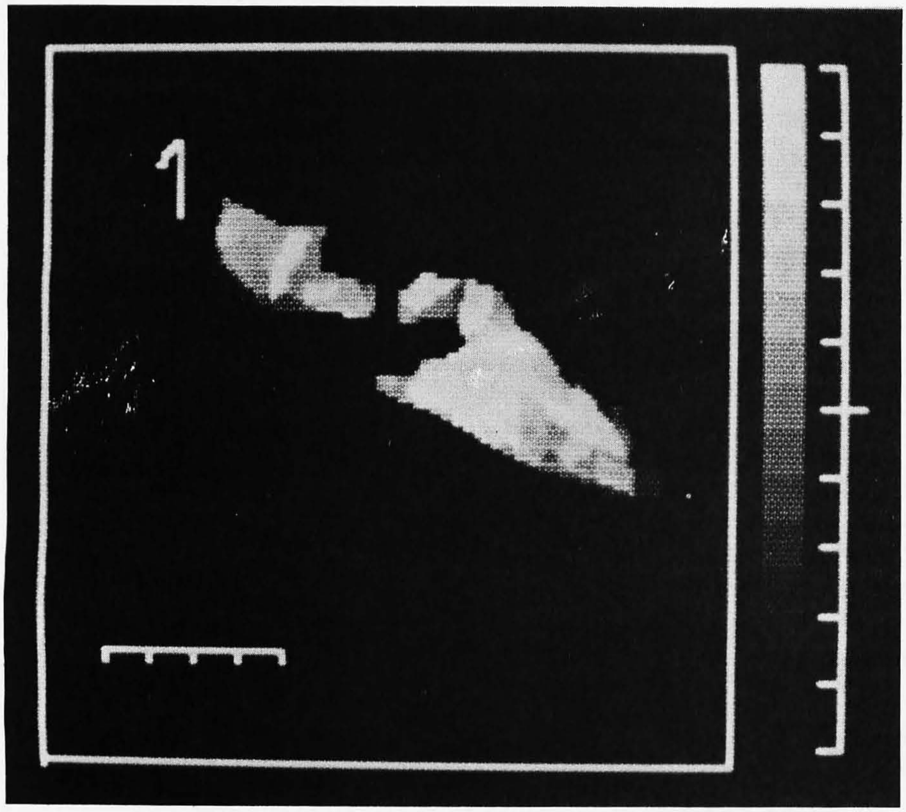

Photo 1: *The area where PROSPECTOR predicts a molybdenum deposit. Given extensive data about the surface, PROSPECTOR used its rules to score areas of favorableness for molybdenum ore. Ore-grade molybdenum was previously found in the bright area on the right. PROSPECTOR predicts more ore will be found in the undrilled bright area on the left. The brighter the area, the higher its rating by PROSPECTOR. The site is in the Mount Tolman area of the state of Washington.*

The Future

We are now witnessing the first transition of expert programs from the comfortable surroundings of research laboratories to the more demanding world outside. For several years, the DENDRAL system has seen regular use by university and industrial chemists throughout the country. The Digital Equipment Corporation is using one version of R1 and is developing versions for other DEC systems. The PROSPECTOR system has been applied to several practical problems of the US Geological Survey and the US Department of Energy. PROSPECTOR has also made its first prediction about the location of a molybdenum deposit. Drilling is underway to see if there is a deposit where PROSPECTOR predicted (see photo 1).

Donald Michie and his colleagues at the University of Edinburgh are developing an expert system similar to PROSPECTOR to diagnose operating problems on North Sea oil platforms. Schlumberger is developing another expert system to interpret the waveforms obtained when instruments are dropped down oil wells. Finally, Michie and the Machine Intelligence Corporation have independently developed the first simplified expert systems that can be run on an Apple computer. The current generation of expert systems is being put to practical use, and many more systems will certainly be built.

Researchers have identified and are attacking several major problems that limit progress in knowledge-based systems. One of these problems concerns software support for research in this field. As our micro expert-system illustrates, BASIC is not the right language for implementing expert systems. Pascal and even LISP are not completely satisfactory either. New languages such as OPS-5, oriented

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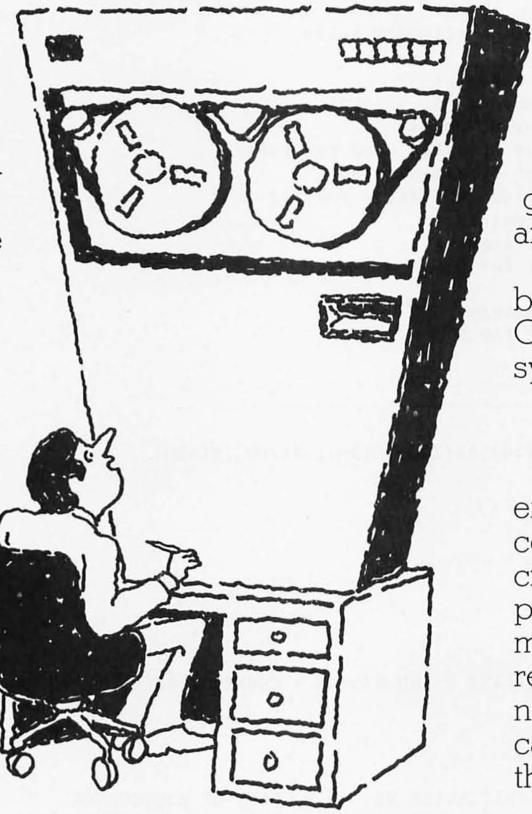

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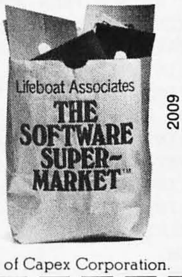

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Listing 1: *A rule-based, animal-identification program in BASIC. This is based on the DIAGNOSE program found in chapter 18 of* LISP *by P H Winston and B K P Horn. The core subroutine is VERIFY (lines 1210 through 1830), which is recursive. Since BASIC does not support recursion, all reentrant subroutines must explicitly save their local values on push-down stacks before transferring control.*

```
00010 REM   A RULE-BASED IDENTIFICATION PROGRAM
00020 REM   Based on the DIAGNOSE program in Chapter 18 of the book
00030 REM   "LISP" by P. H. Winston and B. K. P. Horn
00040 REM
00050 REM   A$ = array of asked questions
00060 REM        A1 = current number of asked questions
00070 REM        A9 = maximum number of asked questions
00080 REM   F$ = array for facts
00090 REM        F1 = current number of facts
00100 REM        F9 = maximum number of facts
00110 REM   H$ = array for top-level hypotheses
00120 REM        H1 = current top-level hypothesis
00130 REM        H8 = current number of top-level hypotheses
00140 REM        H9 = maximum number of top-level hypotheses
00150 REM   Q  = array of rule numbers for deducing a goal hypothesis
00160 REM        (size = R9/5)
00170 REM        Q8 = current number of relevant rules
00180 REM   R$ = array for rules
00190 REM        R1 = current rule index
00200 REM        R2 = current antecedent
00210 REM        R7 = current number of rules
00220 REM        R8 = current number of bytes used for rules
00230 REM        R9 = maximum number of bytes in R$
00240 REM   R  = array of pointers into R$  (size = R9/5)
00250 REM        R1 = current rule pointer
00260 REM   S$ = stack array for strings
00270 REM        S1 = stack pointer for S$
00280 REM        S9 = size of S$
00290 REM   S  = stack array for numbers
00300 REM        S2 = stack pointer for S
00310 REM        S8 = size of S
00320 REM
00330 REM   ------------------------------------------
00340 REM   INITIALIZE
00350 DIM A$(100),F$(100),H$(20),Q(50),R$(250),R(50),S$(200),S(200)
00360 A9 = 100
00370 F9 = 100
00380 H9 = 20
00390 R9 = 250
00400 S8 = 200
00410 S9 = 200
00420 S1 = 0
00430 S2 = 0
00440 PRINT "Hello."
00450 REM   CALL LOADRULES TO INITIALIZE R AND R$; R7 = COUNT OF RULES
00460 GOSUB 3680
00470 IF R7 > 0 THEN 500
00480 PRINT "No rules."
00490 STOP
00500 REM   CALL LOADHYPOTHESES TO INITIALIZE H$, H8 = COUNT OF HYPOTHESES
00510 GOSUB 4100
00520 IF H8 > 0 THEN 550
00530 PRINT "No hypotheses."
00540 STOP
00550 PRINT "I will use my ";R7;" rules to try to establish one of the"
00560 PRINT "following ";H8;" hypotheses:"
00570 FOR H1 = 1 TO H8
00580 PRINT "    ";Z$;H$(H1)
00590 NEXT H1
00600 PRINT
00610 PRINT "Please answer my questions with Y (yes), N (no), or W (why)."
00620 PRINT
00630 REM
00640 REM   THE MAIN LOOP -- DIAGNOSE
00650 REM
00660 A1 = 0
00670 F1 = 0
00680 FOR H1 = 1 TO H8
00690 REM   SETUP ARGUMENTS AND GOTO VERIFY TO ESTABLISH THE TRUTH OF F1$
00700 F1$ = H$(H1)
00710 Y = 1
00720 GOTO 1200
```

Listing 1 continued on page 266

toward production development, and new expert-system-building systems such as AGE, HEARSAY III, and RLL are the first of a new generation of software tools that will simplify system development.

On a more fundamental level, something must be done to shorten the time needed to interview experts and represent their special knowledge in the form of rules. This is often called the knowledge-acquisition problem. Despite several concentrated efforts, it remains a bottleneck. The development of a model containing a few hundred rules may now take several months of the expert's time and even more of the system builder's. Past efforts to speed knowledge acquisition have been along three lines: (1) to develop smart editors that assist in entering and modifying rules, (2) to develop an intelligent interface that can interview the expert and formulate the rules, and (3) to develop a learning system that can induce rules from examples, or by reading textbooks and papers.

Somewhat ironically, to do anything ambitious along these lines seems to require fundamental advances in our understanding of two core AI topics—the representation of knowledge and the use of knowledge! The problem is that although inference networks of rules *do much to* codify the reasoning process that an expert uses in solving a problem, there's still much that goes on inside an expert's head that doesn't appear in the networks. Basically, a knowledge-based system provides a flexible yet precise language that an expert can use to describe the chains of reasoning. We need to develop more expressive languages that allow the expert to articulate more of the nuances and details of thought processes. One of the problems is that it is difficult for experts to describe exactly how they do what they do, especially with respect to their use of judgment, experience, and intuition. We are optimistic that such advances will be made, but will resist the temptation to make more specific guesses.

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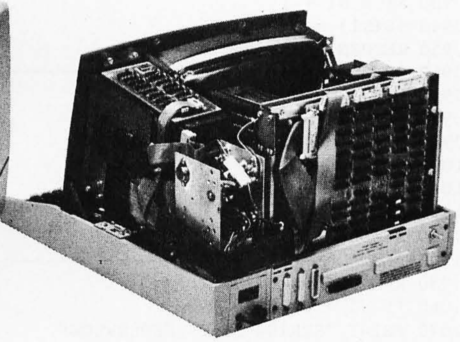

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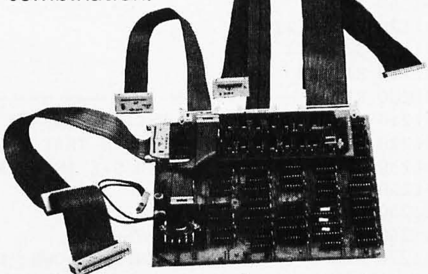

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Listing 1 continued:

```
00730 REM   CALL POP(X$) TO GET ANSWER
00740 GOSUB 1040
00750 IF X$ <> "" THEN 800
00760 NEXT H1
00770 REM   FAILURE
00780 PRINT "No hypothesis can be confirmed."
00790 GOTO 820
00800 REM   SUCCESS
00810 PRINT "I conclude that ";Z$;H$(H1);"."
00820 PRINT
00830 PRINT "Restart or Quit (R or Q)";
00840 INPUT C$
00850 IF C$ = "R" THEN 640
00860 IF C$ <> "Q" THEN 830
00870 STOP
00880 REM   -------------------------------------------
00890 REM   SUBROUTINE PUSH(X$)
00900 IF S1 < S9 THEN 930
00910 PRINT "STRING STACK OVERFLOW"
00920 STOP
00930 S1 = S1 + 1
00940 S$(S1) = X$
00950 RETURN
00960 REM   -------------------------------------------
00970 REM   SUBROUTINE PUSH(X)
00980 IF S2 < S8 THEN 1010
00990 PRINT "NUMBER STACK OVERFLOW"
01000 STOP
01010 S2 = S2 + 1
01020 S(S2) = X
01030 RETURN
01040 REM   -------------------------------------------
01050 REM   SUBROUTINE POP(X$)
01060 IF S1 > 0 THEN 1090
01070 PRINT "STRING STACK UNDERFLOW"
01080 STOP
01090 X$ = S$(S1)
01100 S1 = S1 - 1
01110 RETURN
01120 REM   -------------------------------------------
01130 REM   SUBROUTINE POP(X)
01140 IF S2 > 0 THEN 1170
01150 PRINT "NUMBER STACK UNDERFLOW"
01160 STOP
01170 X = S(S2)
01180 S2 = S2 - 1
01190 RETURN
01200 REM   -------------------------------------------
01210 REM   SUBROUTINE VERIFY(F1$, Y)
01220 REM   ATTEMPTS TO PROVE THAT FACT F1$ IS TRUE
01230 REM   CALL RECALL TO SEE IF WE ALREADY KNOW F1$
01240 F2$ = F1$
01250 GOSUB 1840
01260 IF R2$ <> "" THEN 1760
01270 REM   F1$ NOT CURRENTLY KNOWN; CALL INTHEN TO FIND RULES THAT DEDUCE IT
01280 GOSUB 2100
01290 REM   ANSWER IS IN Q, WITH Q(0) THE COUNT; ARE THERE ANY RULES?
01300 Q8 = Q(0)
01310 IF Q8 > 0 THEN 1360
01320 REM   NO RULES; CALL ASK TO ASK THE USER
01330 GOSUB 2320
01340 IF A1$ = "" THEN 1790
01350 GOTO 1760
01360 REM   CHAIN BACKWARD THROUGH THE RULES RECURSIVELY
01370 Q1 = 1
01380 REM   PUSH NEEDED LOCAL VARIABLES
01390 X$ = F1$
01400 GOSUB 880
01410 X = Y
01420 GOSUB 960
01430 FOR Q2 = 1 TO Q8
01440 X = Q(Q2)
01450 GOSUB 960
01460 NEXT Q2
01470 X = Q8
01480 GOSUB 960
01490 X = Q1
01500 GOSUB 960
```

Listing 1 continued on page 268

the development of expert systems: the exercise of building a knowledge base for a problem area forces the expert to think through the problem in a precise and thorough manner. The resulting codification benefits the basic science itself. For example, models of mineral deposits have appeared for years in the literature of economic geology, but these models have traditionally been expressed in English prose, accompanied by schematic geological sketches and maps. Such models are meaningful to geologists, but they are descriptive rather than predictive. Furthermore, many details are left unstated because the author assumes that the readers will understand what is meant. Since the development of PROSPECTOR, there seems to be more interest among geologists in developing models more precise than those of the past.

We pay dearly for expertise when we need it, whether it's for fixing a home appliance or for finding oil. Knowledge-based expert systems offer the potential of codifying and disseminating expertise to those who don't have it. In effect, knowledge-based expert systems offer the promise of putting experts at everyone's disposal.

A Simple Rule-Based System

Most rule-based expert systems are large programs written in LISP, too big for today's personal computers. However, it is possible to write a small rule-based program that is both entertaining and educational.

The BASIC program shown in listing 1 implements a simple version of the backward-chaining procedure used in MYCIN. This program is essentially a recoding of the DIAGNOSE program used by Winston and Horn in their book *LISP* (see reference 35) to explain rule-based systems, and includes their set of fifteen rules for identifying animals. The network formed by these rules is depicted in figure 5. While these rules are too few and too simple for serious use, you might have fun changing them and creating

Text continued on page 274

MULTI-USER OASIS HAS THE FEATURES PROS DEMAND. READ WHY.

(THEN COMPARE.)

Computer experts (the pros) usually have big computer experience. That's why when they shop system software for Z80 micros, they look for the big system features they're used to. And that's why they like Multi-User OASIS. You will too.

DATA INTEGRITY: FILE & AUTOMATIC RECORD LOCKING

The biggest challenge for any multi-user system is co-ordinating requests from several users to change the same record at the same time.

Without proper co-ordination, the confusion and problems of inaccurate or even destroyed data can be staggering.

Our File and Automatic Record Locking features solve these problems.

For example: normally all users can view a particular record at the same time. But, if that record is being updated by one user, automatic record locking will deny all other users access to the record until the up-date is completed. So records are always accurate, up-to-date and integrity is assured.

Pros demand file & automatic record locking. OASIS has it.

SYSTEM SECURITY: LOGON, PASSWORD & USER ACCOUNTING

Controlling who gets on your system and what they do once they're on it is the essence of system security. Without this control, unauthorized users could access your programs and data and do what they like. A frightening prospect isn't it?

And multi-users can multiply the problem.

But with the Logon, Password and Privilege Level features of Multi-User OASIS, a system manager can specify for each user which programs and files may be accessed— and for what purpose.

Security is further enhanced by User Accounting—a feature that lets you keep a history of which user has been logged on, when and for how long.

Pros insist on these security features. OASIS has them.

EFFICIENCY: RE-ENTRANT BASIC

A multi-user system is often not even practical on computers limited to 64K memory.

OASIS Re-entrant BASIC makes it practical.

How?

Because all users use a single run-time BASIC module, to execute their compiled programs, less memory is needed. Even if you have more than 64K, your pay-off is cost saving and more efficient use of all the memory you have available—because it services more users.

Sound like a pro feature? It is. And OASIS has it.

AND LOTS MORE...

Multi-User OASIS supports as many as 16 terminals and can run in as little as 56K memory. Or, with bank switching, as much as 784K.

Multi-Tasking lets each user run more than one job at the same time.

And there's our BASIC— a compiler, interpreter and debugger all in one. An OASIS exclusive.

Still more: Editor; Hard & Floppy Disk Support; Keyed (ISAM), Direct & Sequential Files; Mail-Box; Scheduler; Spooler; all from OASIS.

Our documentation is recognized as some of the best, most extensive, in the industry. And, of course, there's plenty of application software.

Put it all together and it's easy to see why the real pros like OASIS. Join them. Send your order today.

OASIS

MAKES MICROS RUN LIKE MINIS

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SYSTEMS: Altos; Compucorp; Cromemco; Delta Products; Digital Group; Digital Microsystems; Dynabyte; Godbout; IBC; Index; Intersystems; North Star; Onyx; SD Systems; TRS 80 Mod II; Vector Graphic; Vorimex.

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COMMUNICATIONS PACKAGE (Terminal Emulator; File Send & Receive)	100	15.00
PACKAGE PRICE (All of Above) SINGLE-USER MULTI-USER	500 850	60.00 60.00
FILE SORT	100	15.00
COBOL-ANSI '74	750	35.00

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Signature__________

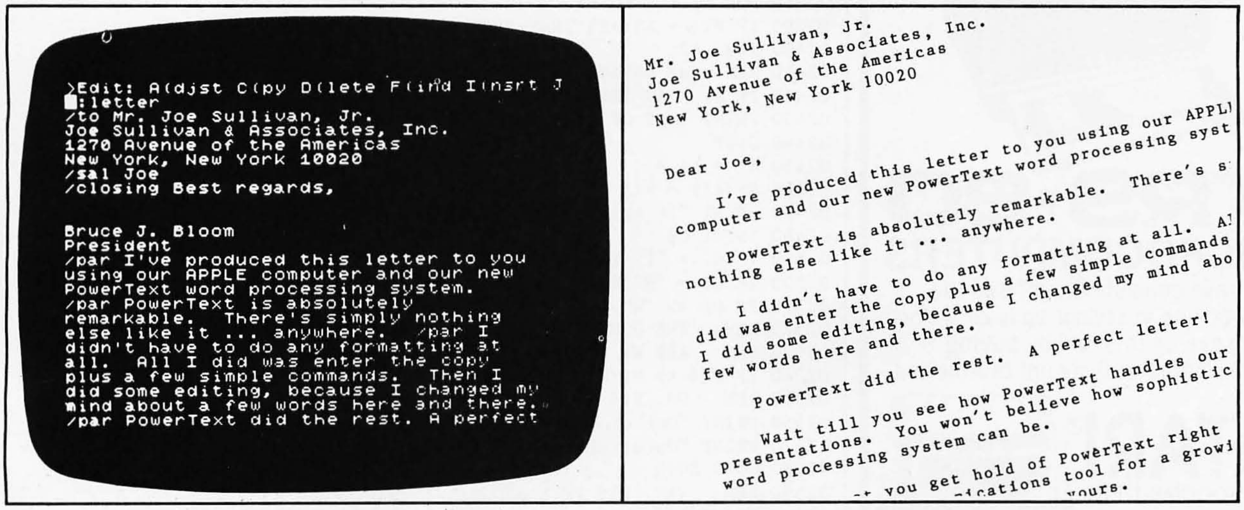
Circle 292 on inquiry card.

Listing 1 continued:

```
01510 REM   SETUP ARGUMENTS AND GOTO TRYRULE+(R1, Y)
01520 R1 = Q(Q1)
01530 Y = 2
01540 GOTO 2840
01550 REM   POP AND SAVE THE ANSWER, AND POP THE LOCAL VARIABLES
01560 GOSUB 1040
01570 X1$ = X$
01580 GOSUB 1120
01590 Q1 = X
01600 GOSUB 1120
01610 Q8 = X
01620 FOR Q2 = Q8 TO 1 STEP -1
01630 GOSUB 1120
01640 Q(Q2) = X
01650 NEXT Q2
01660 GOSUB 1120
01670 Y = X
01680 GOSUB 1040
01690 F1$ = X$
01700 IF X1$ = "T" THEN 1760
01710 REM   RATS, RULE R1 DIDN'T WORK; TRY THE NEXT ONE
01720 Q1 = Q1 + 1
01730 IF Q1 <= Q8 THEN 1380
01740 REM   CURSES, NONE OF THE RULES WORKED
01750 GOTO 1790
01760 REM   SUCCESS
01770 X$ = "T"
01780 GOTO 1810
01790 REM   FAILURE
01800 X$ = ""
01810 REM   PUSH THE ANSWER AND RETURN
01820 GOSUB 880
01830 ON Y GOTO 730,1550,2950,3300
01840 REM   -------------------------------------------
01850 REM   SUBROUTINE RECALL(F2$)
01860 REM   CHECKS TO SEE IF FACT F2$ HAS BEEN RECORDED
01870 R2$ = ""
01880 IF F1 = 0 THEN 1940
01890 FOR I = 1 TO F1
01900 IF F2$ = F$(I) THEN 1930
01910 NEXT I
01920 GOTO 1940
01930 R2$ = F2$
01940 RETURN
01950 REM   -------------------------------------------
01960 REM   SUBROUTINE REMEMBER(F2$)
01970 REM   RECORDS FACT F2$
01980 R1$ = ""
01990 REM   CALL RECALL TO SEE IF ALREADY STORED
02000 GOSUB 1840
02010 IF R2$ <> "" THEN 2090
02020 REM   ADD NEW FACT
02030 IF F1 < F9 THEN 2060
02040 PRINT "OUT OF ROOM FOR RECORDING FACTS"
02050 STOP
02060 F1 = F1 + 1
02070 F$(F1) = F2$
02080 R1$ = F2$
02090 RETURN
02100 REM   -------------------------------------------
02110 REM   SUBROUTINE INTHEN(F1$)
02120 REM   FINDS ALL THE RULES THAT HAVE FACT F1$ AS A CONSEQUENT
02130 Q(0) = 0
02140 REM   LOOP THROUGH THE RULES
02150 FOR R3 = 1 TO R7
02160 REM   FIND THE CONSEQUENTS OF RULE R3
02170 R4 = R(R3) + 2
02180 F2$ = R$(R4)
02190 IF F2$ = "THEN" THEN 2220
02200 R4 = R4 + 1
02210 GOTO 2180
02220 REM   LOOP THROUGH THE CONSEQUENTS
02230 R4 = R4 + 1
02240 F2$ = R$(R4)
02250 IF F2$ = "STOP" THEN 2300
02260 IF R$(R4+1) = "IF" THEN 2300
02270 IF F2$ <> F1$ THEN 2230
02280 Q(0) = Q(0) + 1
02290 Q(Q(0)) = R3
```

Listing 1 continued on page 270

Comes the revolution in Apple word processing. PowerText. From Beaman Porter.



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Bat out a letter on your Apple's keyboard just as fast as you can.

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As you go, just type in simple, short commands to identify the name and address element ... the salutation ... paragraphs ... and sign-off.

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It's a true revolution in Apple word processing software. New ... from Beaman Porter.

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The editing power of PASCAL, the formatting power of PowerText.

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Result: you get perfect formatting ... plus full *insert, delete,* and *global search and replace* capabilities. In one remarkable system.

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And you can use a variety of pitches within any document!

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You never have to worry about page breaks, or winding up with "Yours truly" all by itself on page 2 of your letter.

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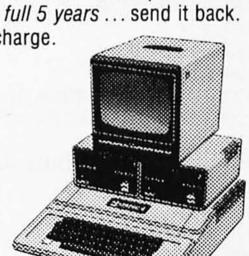
PowerText accommodates up to 12 columns per 132-character line. With individual line spacing for each column.

It lets you left- or right-justify—or center—each column separately. Or print any column in paragraph style. And there are no tab settings to set for columnar reports; PowerText does the arithmetic for you.

PowerText requires 48 K APPLE II or APPLE II PLUS, two disk drives, and PASCAL language system, plus a Qume, Diablo, or Epson printer.

FULL 5-YEAR WARRANTY!

PowerText has been proven with the most demanding tests ... and *texts* ... we could devise. It *always* works. If it should fail to perform *as specified ... for a full 5 years* ... send it back. We'll fix it at no charge.



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Yet PowerText, plus its excellent Manual/ Tutorial, are available now at the Special Introductory Price of only $199. (Manual/Tutorial alone, only $25 ... deductible from the $199 package price when you order the disk later.)

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I understand my PowerText Disk is warranted for a full five years. Should it fail to perform as specified, Beaman Porter, Inc. will fix it for me at no charge.

Circle 37 on inquiry card.

Listing 1 continued:

```
02300 NEXT R3
02310 RETURN
02320 REM   ---------------------------------------------
02330 REM   SUBROUTINE ASK(F1$)
02340 REM   ASKS THE USER ABOUT F1$ AND EXPLAINS ITS REASON
02350 A1$ = ""
02360 REM   HAVE WE ASKED THE USER ABOUT F1$ BEFORE?
02370 IF A1 = 0 THEN 2410
02380 FOR A2 = 1 TO A1
02390 IF F1$ = A$(A2) THEN 2830
02400 NEXT A2
02410 REM   WE HAVEN'T ASKED BEFORE.  IF WE HAVE ROOM, LET'S ASK.
02420 IF A1 < A9 THEN 2450
02430 PRINT "OUT OF ROOM FOR ASKED QUESTIONS"
02440 STOP
02450 A1 = A1 + 1
02460 A$(A1) = F1$
02470 PRINT "Is this true: ";Z$;F1$;
02480 INPUT C$
02490 IF C$ = "Y" THEN 2790
02500 IF C$ = "N" THEN 2830
02510 IF C$ <> "W" THEN 2470
02520 REM   THE USER WANTS TO KNOW WHY I ASKED
02530 REM   ARE WE WORKING ON A RULE?
02540 IF F1$ <> H$(H1) THEN 2590
02550 REM   NO, F1$ IS A TOP-LEVEL HYPOTHESIS
02560 PRINT "One of the possibilities is ";Z$;F1$
02570 PRINT "Unfortunately, I have no way to deduce this except to ask you."
02580 GOTO 2470
02590 REM   YES. F1$ IS A SUBGOAL.  PRINT RULE R1
02600 PRINT "I am trying to use Rule ";R$(R(R1))
02610 R3 = R(R1) + 2
02620 IF R3 = R2 THEN 2670
02630 PRINT "I already know that:"
02640 PRINT Z$;R$(R3)
02650 R3 = R3 + 1
02660 IF R3 < R2 THEN 2640
02670 PRINT "IF:"
02680 PRINT Z$;R$(R3)
02690 R3 = R3 + 1
02700 IF R$(R3) <> "THEN" THEN 2680
02710 PRINT "THEN:"
02720 R3 = R3 + 1
02730 PRINT Z$;R$(R3)
02740 R3 = R3 + 1
02750 IF R$(R3) = "STOP" THEN 2770
02760 IF R$(R3+1) <> "IF" THEN 2730
02770 PRINT
02780 GOTO 2470
02790 REM   THE USER SAYS THAT F1$ IS TRUE; CALL REMEMBER TO RECORD IT
02800 F2$ = F1$
02810 GOSUB 1950
02820 A1$ = "T"
02830 RETURN
02840 REM   ---------------------------------------------
02850 REM   SUBROUTINE TRYRULE+(R1, Y)
02860 REM   TRIES TO APPLY RULE R1
02870 REM   PUSH NEEDED LOCAL VARIABLES
02880 X = R1
02890 GOSUB 960
02900 X = Y
02910 GOSUB 960
02920 REM   SETUP ARGUMENTS AND GOTO TESTIF+(R1, Y)
02930 Y = 3
02940 GOTO 3130
02950 REM   POP THE RESULTS OF TESTIF+ AND RESTORE LOCAL VARIABLES
02960 GOSUB 1040
02970 GOSUB 1120
02980 Y = X
02990 GOSUB 1120
03000 R1 = X
03010 IF X$ = "" THEN 3080
03020 REM   CALL USETHEN
03030 GOSUB 3460
03040 IF U1$ = "" THEN 3080
03050 REM   SUCCESS
03060 X$ = "T"
03070 GOTO 3100
03080 REM   FAILURE
```

Listing 1 continued on page 272

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MODEMS AND COUPLERS

Connect your Apple, TRS–80 or any other computer or terminal to the phone lines!

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Penril 300/1200

Penril 300/1200—Bell 212A style $799
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USR-330D $339
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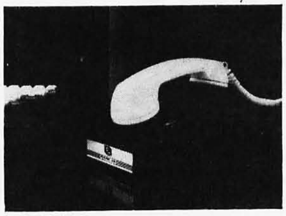

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Bell 103/113 style $179
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DEC VT100 ... $1668
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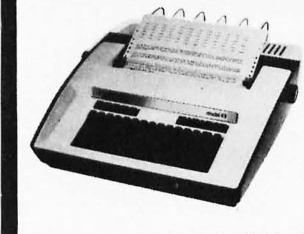

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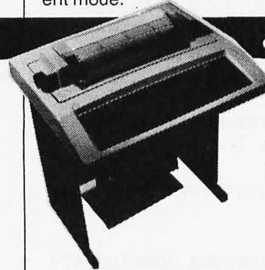

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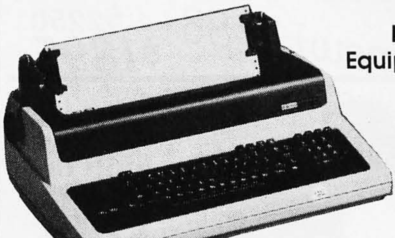

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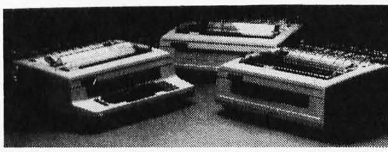
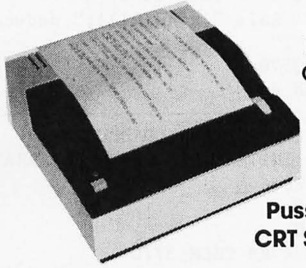


5520 KSR Spinwriter $3088
55 CPS. Impact printer. Selectric print quality. Changeable print fonts. 110, 300 and 1200 baud data rate. Numeric keypad. Friction and tractor feed.

5510 Spinwriter $2754
55 CPS. Impact printer. Selectric print quality. Changeable print fonts. 110, 300 and 1200 baud data rate. Friction and tractor feed.



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650/655 Pussycat CRT Screen Printer. $899
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Listing 1 continued:

```
03090 X$ = ""
03100 REM   PUSH THE ANSWER AND RETURN
03110 GOSUB 880
03120 ON Y GOTO 730,1550,2950,3300
03130 REM   ------------------------------------------
03140 REM   SUBROUTINE TESTIF+(R1, Y)
03150 REM   CHECKS ANTECEDENTS TO SEE IF RULE R1 IS APPLICABLE
03160 R2 = R(R1) + 2
03170 F2$ = R$(R2)
03180 IF F2$ = "THEN" THEN 3410
03190 REM   PUSH NEEDED LOCAL VARIABLES
03200 X = Y
03210 GOSUB 960
03220 X = R1
03230 GOSUB 960
03240 X = R2
03250 GOSUB 960
03260 REM   SETUP ARGUMENTS AND GOTO VERIFY
03270 Y = 4
03280 F1$ = F2$
03290 GOTO 1200
03300 REM   POP ANSWER FROM VERIFY AND RESTORE LOCAL VARIABLES
03310 GOSUB 1040
03320 GOSUB 1120
03330 R2 = X
03340 GOSUB 1120
03350 R1 = X
03360 GOSUB 1120
03370 Y = X
03380 IF X$ = "" THEN 3430
03390 R2 = R2 + 1
03400 GOTO 3170
03410 REM   SUCCESS
03420 X$ = "T"
03430 REM   PUSH THE ANSWER AND RETURN
03440 GOSUB 880
03450 ON Y GOTO 730,1550,2950,3300
03460 REM   ------------------------------------------
03470 REM   SUBROUTINE USETHEN(R1)
03480 REM   APPLIES RULE R1 AND PRINTS NEW DEDUCTIONS
03490 U1$ = ""
03500 REM   FIND THE CONSEQUENTS
03510 R2 = R(R1) + 2
03520 F2$ = R$(R2)
03530 IF F2$ = "THEN" THEN 3560
03540 R2 = R2 + 1
03550 GOTO 3520
03560 REM   LOOP THROUGH CONSEQUENTS
03570 R2 = R2 + 1
03580 F2$ = R$(R2)
03590 IF F2$ = "STOP" THEN 3670
03600 IF R$(R2+1) = "IF" THEN 3670
03610 REM   CALL REMEMBER TO ASSERT THE CONSEQUENT
03620 GOSUB 1950
03630 IF R1$ = "" THEN 3570
03640 PRINT "Rule ";R$(R(R1));" deduces ";Z$;F2$
03650 U1$= "T"
03660 GOTO 3570
03670 RETURN
03680 REM   ------------------------------------------
03690 REM   SUBROUTINE LOADRULES
03700 REM   INITIALIZES THE RULE ARRAYS R$ AND R WITH THE RULE DATA
03710 READ Z$
03720 R7 = 0
03730 R8 = 0
03740 IF R8 < R9 THEN 3770
03750 PRINT "OUT OF ROOM FOR RULES"
03760 STOP
03770 REM   READ NEXT RULE INTO R$
03780 REM   FORMAT: <name> IF <ant> ... <ant> THEN <con> ... <con>
03790 R8 = R8 + 1
03800 READ R$(R8)
03810 IF R$(R8) <> "IF" THEN 3840
03820 R7 = R7 + 1
03830 R(R7) = R8 - 1
03840 IF R$(R8) <> "STOP" THEN 3740
03850 RETURN
03860 REM   RULE DATA
03870 DATA "ANIMAL "
```

Listing 1 continued on page 274

$30 lets you take advanced VisiCalc™ lessons from VisiCalc's creators.

Introducing SATN from Software Arts, Inc., the creators of the VisiCalc program. SATN (Software Arts Technical Notes) is a publication offering on-going support to all VisiCalc users—from novice to expert.

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Listing 1 continued:

```
03880 DATA "R1","IF","HAS HAIR","THEN","IS MAMMAL"
03890 DATA "R2","IF","GIVES MILK","THEN","IS MAMMAL"
03900 DATA "R3","IF","HAS FEATHERS","THEN","IS BIRD"
03910 DATA "R4","IF","FLIES","LAYS EGGS","THEN","IS BIRD"
03920 DATA "R5","IF","EATS MEAT","THEN","IS CARNIVORE"
03930 DATA "R6","IF","HAS POINTED TEETH","HAS CLAWS","HAS FORWARD EYES"
03940 DATA   "THEN","IS CARNIVORE"
03950 DATA "R7","IF","IS MAMMAL"."HAS HOOFS","THEN","IS UNGULATE"
03960 DATA "R8","IF","IS MAMMAL","CHEWS CUD","THEN","IS UNGULATE"
03970 DATA "R9","IF","IS MAMMAL","IS CARNIVORE","HAS TAWNY COLOR"
03980 DATA   "HAS DARK SPOTS","THEN","IS CHEETAH"
03990 DATA "R10","IF","IS MAMMAL","IS CARNIVORE","HAS TAWNY COLOR"
04000 DATA   "HAS BLACK STRIPES","THEN","IS TIGER"
04010 DATA "R11","IF","IS UNGULATE","HAS LONG NECK","HAS LONG LEGS"
04020 DATA   "HAS DARK SPOTS","THEN","IS GIRAFFE"
04030 DATA "R12","IF","IS UNGULATE","HAS BLACK STRIPES","THEN","IS ZEBRA"
04040 DATA "R13","IF","IS BIRD","DOES NOT FLY","HAS LONG NECK"
04050 DATA   "IS BLACK AND WHITE","THEN","IS OSTRICH"
04060 DATA "R14","IF","IS BIRD","DOES NOT FLY","SWIMS","IS BLACK AND WHITE"
04070 DATA   "THEN","IS PENGUIN"
04080 DATA "R15","IF","IS BIRD","FLIES WELL","THEN","IS ALBATROSS"
04090 DATA "STOP"
04100 REM   ------------------------------------------
04110 REM   SUBROUTINE LOADHYPOTHESES
04120 REM   INITIALIZES THE HYPOTHESIS ARRAY H$ WITH HYPOTHESIS DATA
04130 H8 = 0
04140 IF H8 < H9 THEN 4170
04150 PRINT "OUT OF ROOM FOR HYPOTHESES"
04160 STOP
04170 REM   READ NEXT HYPOTHESIS
04180 H8 = H8 + 1
04190 READ H$(H8)
04200 IF H$(H8) <> "STOP" THEN 4180
04210 H8 = H8 - 1
04220 RETURN
04230 REM   HYPOTHESIS DATA
04240 DATA "IS ALBATROSS","IS PENGUIN","IS OSTRICH","IS ZEBRA"
04250 DATA "IS GIRAFFE","IS TIGER","IS CHEETAH","STOP"
04260 END
```

Text continued from page 266:
new ones. Moreover, by replacing these rules with rules for identifying, say, birds or flowers, you can use the same program for many other identification tasks. A more practical application might be a set of rules for diagnosing what is at fault in a malfunctioning toilet or washing machine.

The rules themselves appear in the DATA statements in lines 3880 through 4080. Each rule has the form:

<name>,"IF",<a>, ... ,<a>, "THEN",<c>, ... ,<c>

For example, "R7","IF","IS MAMMAL","HAS HOOFS","THEN","IS UNGULATE". The name of the rule can be any convenient string. The antecedents <a> and consequents <c> are strings that correspond to propositions about the animal and they may be true or false. If all the antecedents are found to be true, the program can use the rule to assert the truth of all the consequents. The rules are terminated by the string "STOP".

In addition to the rules, the pro-

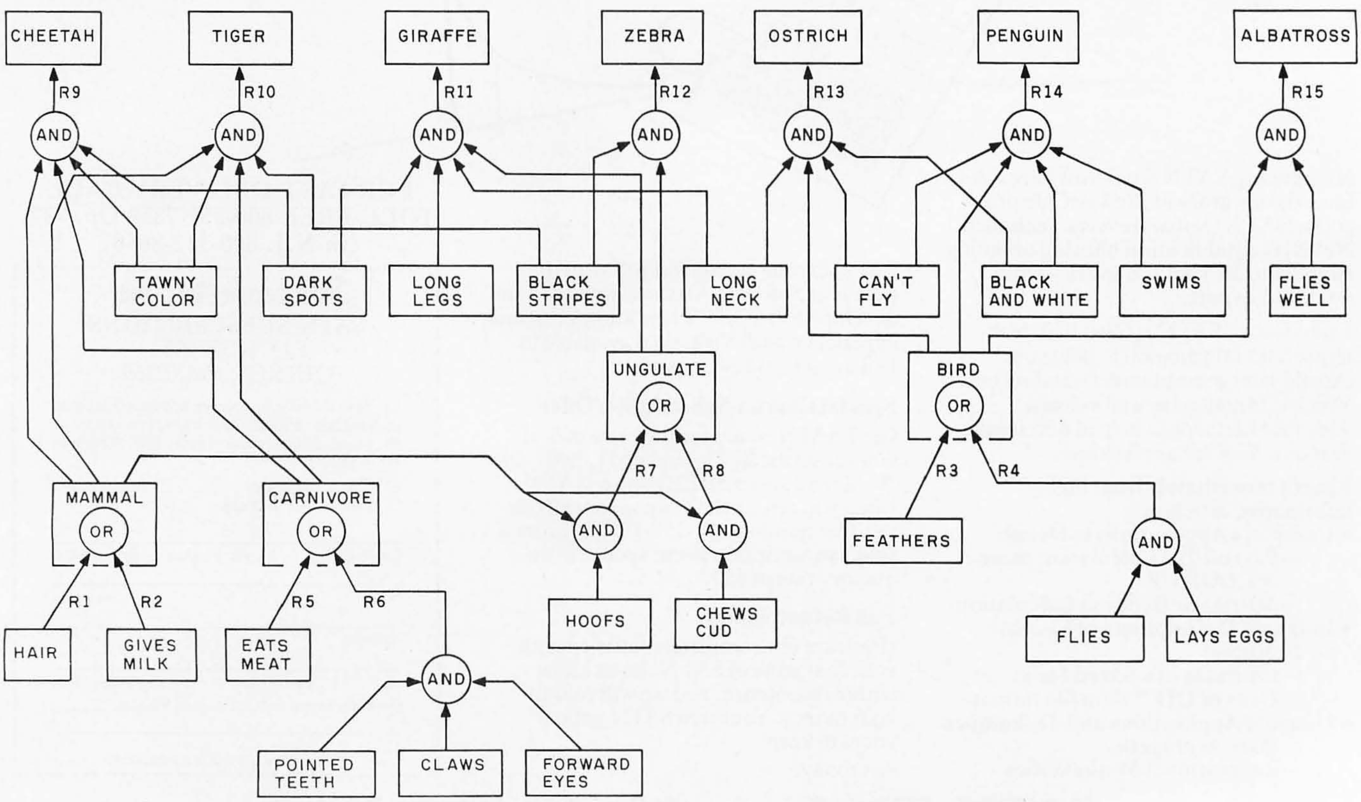

Figure 5: *A sample network for a simple rule-based system. Boxes represent assertions, circles represent ways of combining assertions, and the labels R1, R2, etc, identify rules. The diagram corresponds to the rules given in lines 3880 through 4080 of listing 1.*

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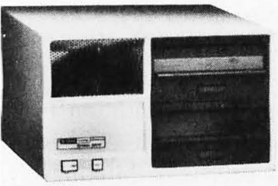

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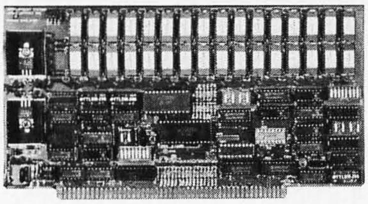

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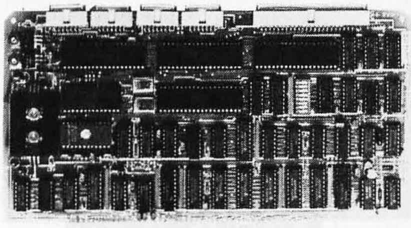

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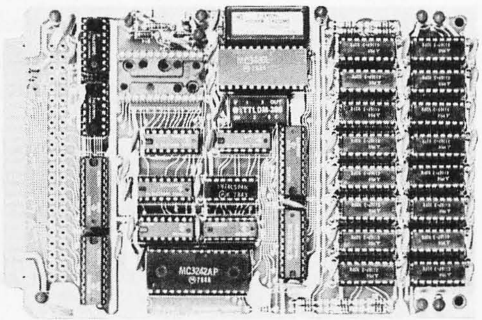

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gram uses a set of hypotheses, which appear in the DATA statements in lines 4240 through 4250. In this case, the hypotheses are that the animal is either an albatross, a penguin, an ostrich, a zebra, a giraffe, a tiger, or a cheetah. The goal of the program is to establish the truth of one of these hypotheses.

The program operates by trying the hypotheses one at a time. For each hypothesis, the program scans the list of rules to see if the hypothesis can be deduced. If so, the antecedents for the relevant rules become new subhypotheses to be established, and the program looks for rules for deducing these antecedents. The program chains backward through the rules until no deductions can be made, at which point the program asks the user if the subhypothesis it is working on is true.

The core subroutine that implements this strategy is called VERIFY (see lines 1210 through 1830). VERIFY tries to determine if its argument F1$ is true. The argument F1$ represents a hypothesis or subhypothesis. If the truth of F1$ has already been recorded, VERIFY returns immediately. If there are no rules for deducing F1$, and if VERIFY has not asked the user about F1$ before, it asks. Otherwise, VERIFY applies TRYRULE+ to each of the rules in turn until it either meets with success or exhausts the rules.

The only thing that complicates the coding of this simple strategy is that TRYRULE+ uses TESTIF+ to see if all the antecedents for the rule are true, and TESTIF+ checks the antecedents by calling VERIFY. Thus, VERIFY is recursive, and BASIC does not support recursion. Therefore, all the reentrant subroutines must explicitly save their local variables on push-down stacks before transferring control to one another, restoring those values upon return. To see one reason why AI workers prefer LISP, which takes care of all this bookkeeping automatically, you need only glance at the simpler version of this same program in Winston and Horn's book.

Pascal would be a better language than BASIC for our program because Pascal supports recursion and allows user-defined data structures (eg: using records and the type statement), as well as providing an easy-to-understand block structure. We chose to write this program in BASIC rather than Pascal because more personal computers have BASIC. (We hope our use of BASIC will not contribute to the perpetuation of this condition!)

Listing 2 shows an example of the dialogue when the user was thinking of a cheetah. A look at the rules shows why the program asked the questions it did. Working the first hypothesis (albatross), the program tried to use rule R15, which set up the subgoal of seeing if the animal was a bird. Rules R3 and R4 were relevant, so the program tried rule R3 and asked if the animal had feathers. The program soon ruled out the possibility of a bird, so it skipped the penguin and ostrich hypotheses. Working on rule R12 for the zebra hypothesis, on rule R11 for the ungulate subhypothesis, and on rule R1 for the mammal sub-subhypothesis, the program successively established that the animal was a mammal, was not an ungulate, and was a carnivore called a cheetah.

It is worth noting that the backward-chaining strategy is different from the classical divide-and-conquer approach used in binary search. With four well-chosen questions, it is possible to make the one-out-of-fifteen decision that required nine questions in this example. Before concluding that rule-based programs are hopelessly inefficient, you should note that the rules do make use of subclasses and sub-subclasses, much as is done in binary search. Thus, once it is learned that the animal is not a bird, for example, no more questions concerning birds will be asked. The main difference is that this particular program does not ask directly if the animal is a bird, but rather asks for primitive observations that allow "birdness" to be deduced.

Listing 2: *A sample run of the identification program shown in listing 1. The program asks questions and makes deductions, when possible, based on the answers. The program always cites the rule used to make a deduction.*

```
Hello.
I will use my  15  rules to try to establish one of the
following  7  hypotheses:
    ANIMAL IS ALBATROSS
    ANIMAL IS PENGUIN
    ANIMAL IS OSTRICH
    ANIMAL IS ZEBRA
    ANIMAL IS GIRAFFE
    ANIMAL IS TIGER
    ANIMAL IS CHEETAH

Please answer my questions with Y (yes), N (no), or W (why).

Is this true: ANIMAL HAS FEATHERS ?N
Is this true: ANIMAL FLIES ?N
Is this true: ANIMAL HAS HAIR ?Y
Rule R1 deduces ANIMAL IS MAMMAL
Is this true: ANIMAL HAS HOOFS ?N
Is this true: ANIMAL CHEWS CUD ?N
Is this true: ANIMAL EATS MEAT ?Y
Rule R5 deduces ANIMAL IS CARNIVORE
Is this true: ANIMAL HAS TAWNY COLOR ?Y
Is this true: ANIMAL HAS BLACK STRIPES ?W
I am trying to use Rule R10
I already know that:
ANIMAL IS MAMMAL
ANIMAL IS CARNIVORE
ANIMAL HAS TAWNY COLOR
IF:
ANIMAL HAS BLACK STRIPES
THEN:
ANIMAL IS TIGER

Is this true: ANIMAL HAS BLACK STRIPES ?N
Is this true: ANIMAL HAS DARK SPOTS ?Y
Rule R9 deduces ANIMAL IS CHEETAH
I conclude that ANIMAL IS CHEETAH.
```

To gain efficiency, you might want to change the program so it will ask the user about intermediate hypotheses, resorting to deduction only when the user gives a "don't know" response. This illustrates how the rule-based approach actually provides great flexibility by separating the control strategy (as implemented in VERIFY) from the knowledge base (as represented by the rules).

The rule-based identification system just described is at best a toy. Although this system illustrates the important principle of the separation of the rule base from the general-reasoning program, the system lacks many important features included in state-of-the-art research systems. Among the features present in most state-of-the-art knowledge-based systems, but lacking in our toy program, are the following:

- immediate propagation of inferences
- negative inferences
- plausible inference's ability to handle mutually exclusive categories
- contextual constraints
- degrees of certainty in user's answers
- information volunteered by the user
- flexible control structure

But toys are fun, and are often effective teachers. Enjoy. ■

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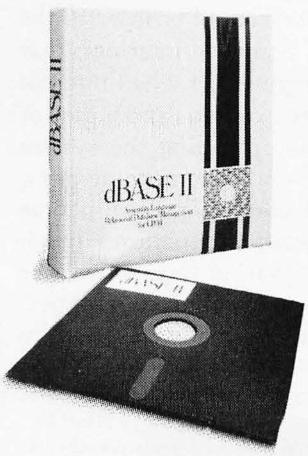

Ashton-Tate

The Atari Tutorial

Part 1: The Display List

Chris Crawford
1272 Borregas Ave
Sunnyvale CA 94086

Editor's Note: *Although I have always considered myself an "Apple person" (I have a disk-based Apple II at home), it was exciting to attend a two-day seminar for prospective Atari programmers given by Chris Crawford, Lane Winner, and Mike Ekberg, all of Atari Inc. Once I learned about the internal structure of the Atari 400 and 800 computers, I realized the tremendous potential these machines have.*

We at BYTE are proud to present "The Atari Tutorial," a series of articles written by members of the Atari staff. The subjects include: the display list, graphics indirection and character sets, player-missile graphics, display-list interrupts, scrolling, and Atari BASIC. This series of articles is adapted from De Re Atari, *a forthcoming book on the internal structure of Atari computers, to be published in December 1981 by Atari Inc.*

*This first article, which is on display lists, is by Chris Crawford, who with Lane Winner coauthored the article "An Introduction to Atari Graphics," which we published in the January 1981 BYTE, page 18. "The Atari Tutorial" will cover in greater detail many of the interesting points only mentioned in the first article. We hope you enjoy the series....*GW

The Atari personal-computer system is a second-generation personal computer. First and foremost, it is a consumer computer. The entire thrust of its design is to make the consumer comfortable with the computer. This consumer orientation reveals itself in many ways. First, the consumer is protected from mistakes by items such as keystone-shaped connectors that cannot be inserted the wrong way, a power interlock that turns the computer off when internal electronics are exposed, and a pair of plastic shields protecting the system reset key. Second, the machine has a great deal of graphics power; people generally respond to pictures much more readily than to text. Third, the machine has good sound capabilities; again, people normally respond to direct sensory input better than to indirect textual messages. Finally, the computer has joysticks and paddles for more direct tactile input than is possible with keyboards. The point is not that the Atari personal-computer system has a lot of features, but rather that the features are all part of a consistent design philosophy aimed at the consumer. The designer who does not appreciate this fundamental fact will be working against the grain of the system.

The internal layout of the Atari 400 and 800 computers (which are electrically equivalent to each other) is very different from that of other systems. They do have a microprocessor (a 6502), RAM (random-access read/write memory), ROM (read-only memory), and a PIA (peripheral interface adapter). However, they also have three special-purpose LSI (large-scale integration) devices known as ANTIC, POKEY, and CTIA. These devices were designed by Atari engineers primarily to take much of the burden of housekeeping from the 6502, freeing the 6502 to concentrate on computations. While they were at it, they designed a great deal of power into these devices. Each is almost as big (in terms of silicon area) as a 6502, so the three of them together provide a tremendous amount of power. Mastering the Atari 400/800 is primarily a matter of mastering these three chips, a task we hope will be aided by this series of tutorial articles.

Principles of Television Display

In order to understand the graphics capabilities of the Atari personal-computer system, you must first understand the rudiments of how a television set works. Television sets use a *raster-scan display system*. An electron beam is generated at the rear of the television tube and shot toward the screen. Along the way, it passes between sets of horizontal and vertical coils or plates that, if energized, can deflect the beam to make it strike any point on the screen. The electronics inside the television set cause the beam to sweep across the screen in a regular fashion. The beam's intensity can be controlled: if you make the beam more intense, the spot being struck on the screen glows brightly; if you make it less intense, the spot glows dimly or not at all.

The beam starts at the top left corner of the screen and traces horizontally across the screen. As it sweeps across the screen, the changes in intensity paint an image on the screen. When the beam reaches the right edge of the screen, it is turned off, brought

This article appears in slightly different form in De Re Atari, *a book published by Atari Inc, and is reproduced with its express permission.*

back to the left side of the screen, and moved down a notch. It then turns back on and sweeps across the screen again. This process is repeated for 262 sweeps across the screen. (There actually are 525 sweeps across the screen in an alternating system known as *interlace*. I will ignore interlace and act as if the television has only 262 lines.) These 262 lines fill the screen from top to bottom. At the bottom of the screen (after the 262nd line is drawn), the electron beam is turned off and returned to the upper left corner of the screen. Then it starts the cycle over again. This entire cycle happens sixty times a second.

Now for some jargon: a single trace of the beam across the screen is called a *horizontal scan line*. A horizontal scan line is the fundamental unit of measurement of vertical distance on the screen. You state the height of an image by specifying the number of horizontal scan lines it spans. The period during which the beam returns from the right edge to the left edge is called the *horizontal blank*. The period during which the beam returns from the bottom to the top of the screen is called the *vertical blank*. The entire process of drawing a screen takes 16,684 μs. The vertical-blank period is about 1400 μs. The horizontal blank takes 14 μs, while a single horizontal scan line takes 64 μs.

Most television sets are designed with *overscan*; they spread the image out so the edges of the picture are off the edge of the television tube. This guarantees that you have no unsightly borders in your picture. It is very bad for computers, though, because screen information that is off the edge of the picture does you no good. For this reason, the picture the computer puts out must be somewhat smaller than what the television can theoretically display. For this reason, only 192 horizontal scan lines are normally used by the Atari display. Thus, the normal limit of resolution of a television set used with the Atari 400/800 is 192 pixels (or picture elements) vertically. (Of course, a color monitor can do much better than that.)

The standard unit of horizontal distance is the *color clock*. You specify the width of an image by stating how many color clocks wide it is. There are 228 color clocks in a single horizontal scan line, with a maximum of 176 actually visible. Thus, the ultimate limit for full color horizontal resolution with a standard color television is 176 pixels. With the computer, you can go even finer and control individual half-clocks. This gives a horizontal resolution of 352 pixels. However, use of this feature produces interesting color effects known as *color artifacts*. Color artifacts can be a nuisance if they are not desired; they can be a boon to the programmer who desires additional color and is not fazed by their restrictions.

Microcomputer Displays

The fundamental problem any microcomputer has in using a raster-scan television for display purposes is that the television display is a dynamic process. Because of this, the television does not remember the image. Consequently, the computer must remember the screen image and constantly send a signal to the television telling it what to display. This process of sending information to the television is a continuous process requiring full-time attention. For this reason, most microcomputers have special hardware circuits that handle the television. The basic arrangement is the same on virtually all systems:

microprocessor → screen RAM →
video hardware → TV screen

The microprocessor writes information to the screen RAM area that holds the screen data. The video hardware is constantly accessing this RAM area, getting screen data and converting them into television signals. These signals go to the television, which then displays the information. The screen memory is mapped onto the screen in the same order in which it is stored. That is, the first byte in the screen memory

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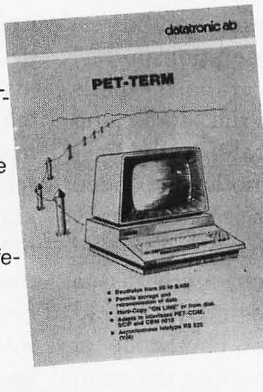

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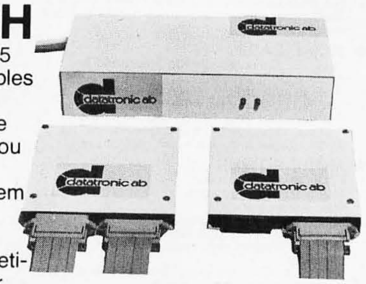

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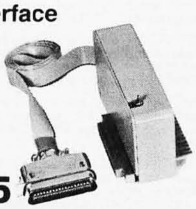

This IEEE => Centronics interface is especially constructed for the PET. It is fully addressable and translates from PET-ASCII to Standard ASCII in two different modes, corresponding to PET's graphic and upper/lower case modes. This is available through a built-in switch.

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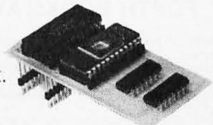

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maps to the top left corner of the screen, the second byte maps one position to the right, then the third, the fourth, and so on to the last byte that is mapped to the lower right corner of the screen.

The quality of the image that gets to the screen depends on two factors: how sophisticated the video hardware is, and how much screen memory is used. The simplest arrangement is used by the Radio Shack TRS-80 and the Commodore PET. These machines allocate a specific 1 K bytes of RAM as screen memory. The video-hardware circuits simply pull data out of this area, interpret them as characters (using a character set in ROM), and put the resulting characters on the screen. Each byte represents one character, allowing a choice of 256 different characters in the character set. With 1 K bytes of screen RAM, 1024 characters can be displayed on the screen. There isn't much that can be done to modify this arrangement.

The Apple II, from Apple Computer Inc, uses more advanced video hardware. Three graphics modes are provided: text, low-resolution (lo-res) graphics, and high-resolution (hi-res) graphics. The text graphics mode operates much as the PET and TRS-80 displays operate. In the low-resolution graphics mode, the video hardware reaches into screen memory and interprets it differently. Instead of interpreting each byte as a character, each byte is interpreted as two blocks of color. The value of each block (4 bits) specifies the color of a single pixel. In the high-resolution graphics mode, each bit in screen memory is mapped to a single pixel. If the bit is on, the pixel gets color in it; if the bit is off, the pixel stays dark. The situation is complicated by a variety of design nuances in the Apple, but that is the basic idea.

The important point is that the Apple has three display modes—three completely different ways of interpreting the data in screen memory. The Apple video hardware is intelligent enough to interpret a screen-memory byte as either an 8-bit character (text mode), two 4-bit color nybbles (low-resolution mode), or 7 individual bits for a bit map (high-resolution mode).

Atari 400/800 Display List

The Atari 400/800 display-list system represents a generalization of these systems. Where the PET and TRS-80 have one mode and the Apple has three modes, the Atari 400/800 has fourteen modes. A second important difference is that Atari 400/800 display modes can be mixed on the screen. You are not restricted to a choice between a screen full of text or a screen full of graphics. Any collection of the fourteen Atari graphics modes can be displayed on the screen simultaneously. The third important difference is that the Atari 400/800 screen RAM can be located *anywhere* in the address space of the computer and moved around while the program is running, whereas the other machines use fixed-screen memory areas.

This generality is made possible by a video microprocessor called ANTIC. Where earlier systems used rather simple video circuitry, Atari designed a full-scale microprocessor just to handle the intricacies of the television display. ANTIC is a true microprocessor—it has an instruction set, a program, and data. The program for ANTIC is called the *display list*. The display list specifies three things: where the screen data can be found, what display modes to use to interpret the screen data, and what special display options (if any) should be implemented.

When using the display list, it is important to shed the old view of a screen as a homogeneous image in a single mode and see it instead as a stack of *mode lines*. A mode line is a collection of horizontal scan lines. It stretches horizontally all the way across the screen. An Atari graphics 2 mode line is 16 horizontal scan lines high, while a graphics 7 mode line is only 2 scan lines high. Many graphics modes available from BASIC are homogeneous; an entire screen of a single mode is set up. But you must not limit your imagination to this pat-

Value of Bit Pair Binary	Decimal	Atari Color Register Used
00	0	COLBAK
01	1	COLPF0
10	2	COLPF1
11	3	COLPF2

Table 1: *Atari color-register assignment in four-color map mode.*

tern; with the display list, you can create any sequence of mode lines down the screen. The display list is a collection of code bytes that specify that sequence.

ANTIC's Instruction Set

ANTIC's instruction set is rather simple. There are four classes of instructions: map-mode instructions, character-mode instructions, blank-line instructions, and jump instructions. Map-mode instructions cause ANTIC to display a mode line with simple colored pixels (no characters). Character-mode instructions cause ANTIC to display a mode line with characters in it. Blank-line instructions cause ANTIC to display a number of horizontal scan lines with a solid background color. Jump instructions are analogous to a 6502 JMP instruction; they reload ANTIC's program counter with a new value. There are also four special options that can sometimes be specified by setting a designated bit in the ANTIC instruction. These options are: *display-list interrupt* (DLI), *load-memory scan* (LMS), *vertical scroll*, and *horizontal scroll*.

Map-mode instructions cause ANTIC to display a mode line containing pixels with solid color in them. The color that is displayed comes from a color register. The choice of color register is specified by the value of the screen data. In four-color map modes (BASIC modes 3, 5, and 7, and ANTIC modes hexadecimal 8, A, D, and E), a pair of bits is required to specify a color register; these values are given in table 1. [*Unfortunately, the graphics mode numbers in BASIC do not correspond to the mode numbers used by ANTIC; this often causes confusion....*GW]

Since only 2 bits are needed to specify one pixel, four pixels are encoded in each screen-data byte. For example, a byte of screen data containing the hexadecimal value 1B would display four pixels; the first would be the background, the second would be color register 0, the third would be color register 1, and the fourth would be color register 2:

hexadecimal 1B
= binary 00011011
= 00 01 10 11

In two-color map modes (BASIC modes 4, 6, and 8, and ANTIC modes hexadecimal 9, B, C, and F), each bit specifies one of two color registers. A bit value of 0 selects background color for the pixel; a bit value of 1 selects color register 0 for the pixel. Eight pixels can be stored in one screen-data byte.

There are eight different map-display modes. They differ in the number of colors they display (two colors versus four colors), the vertical size one mode line occupies (1, 2, 4,

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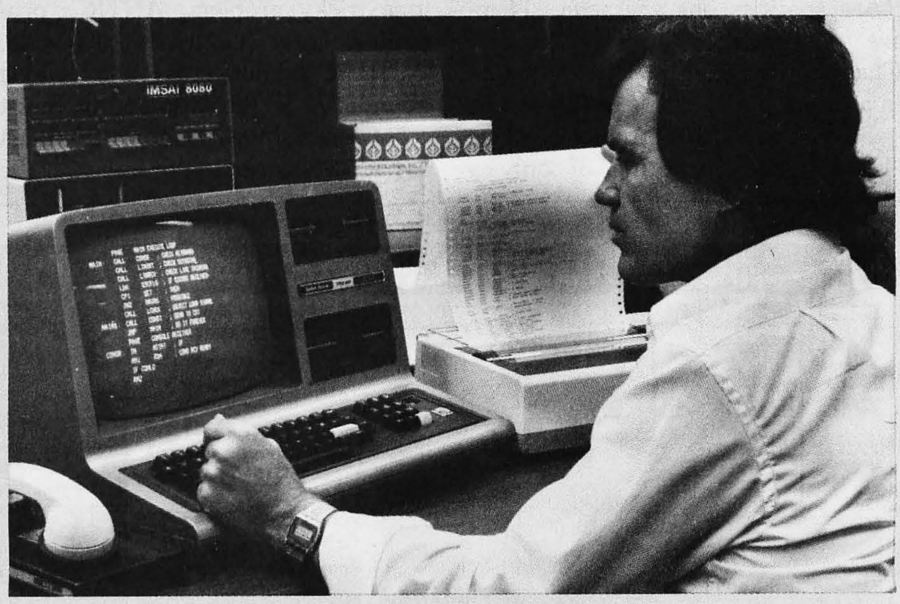

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ANTIC Mode	BASIC Mode	Number of Colors	Scan Lines Per Mode Line	Pixels Per Mode Line	Bytes Per Line	Bytes Per Screen
2	0	2	8	40	40	960
3	none	2	10	40	40	760
4	none	4	8	40	40	960
5	none	4	16	40	40	480
6	1	5	8	20	20	480
7	2	5	16	20	20	240
8	3	4	8	40	10	240
9	4	2	4	80	10	480
A	5	4	4	80	20	960
B	6	2	2	160	20	1920
C	none	2	1	160	20	3840
D	7	4	2	160	40	3840
E	none	4	1	160	40	7680
F	8	2	1	320	40	7680

Table 2: *Atari graphics modes and their characteristics. Note that the same graphics mode is given a different number by BASIC and by ANTIC. The ANTIC mode number refers to one mode* line *of a given kind of graphics, while the BASIC mode number refers to a certain arrangement of mode lines (most or all of which are the given kind of graphics) that defines an entire* screen *of video display.*

or 8 scan lines), and the number of pixels that fit horizontally into one mode line (40, 80, 160, or 320). Thus, some map modes give better resolution; these will require more screen memory. Table 2 presents this information for all modes.

Character-mode instructions cause ANTIC to display a mode line with characters in it. Each byte in screen RAM specifies one character. There are six character-display modes. Character displays will be discussed in a future BYTE article in this series.

Blank-line instructions produce "blank" lines consisting of only a solid background color. There are eight blank-line instructions; they specify skipping one through eight blank lines.

There are two jump instructions. The first (JMP) is a direct jump; it reloads ANTIC's program counter with a new address that follows the JMP instruction as an operand. Its only function is to provide a solution to a tricky problem. ANTIC's program counter is only 10 bits wide. Thus, it cannot cross a 1 K-byte boundary. If the display list must cross a 1 K-byte boundary, it must use a JMP instruction to hop over the boundary. This means that display lists are not fully relocatable.

The second jump instruction (JVB) is more commonly used. It reloads the program counter with the value in the operand and waits for the television to perform a vertical blank. This instruction is normally used to end a display list by jumping to the top of the display list. Jumping to the top turns it into an infinite loop; ANTIC waits for vertical blank to insure that the infinite loop is synchronized to the display cycle of the television. Both JMP and JVB are 3-byte instructions; the first byte is the operation code (JMP or JVB), the second and third bytes are the address to jump to (low byte, then high byte).

The four special options mentioned previously will be discussed in future articles in this series. However, the load-memory scan option must have a preliminary explanation. This option is selected by setting bit 6 of a map-mode or a character-mode instruction byte. When ANTIC encounters such an instruction, it will load its memory-scan counter with the two following bytes. This memory-scan counter tells ANTIC where the screen memory is, and ANTIC begins fetching display data from this area. The LMS instruction is a 3-byte instruction: a 1-byte operation code followed by 2 bytes of operand. In simple display lists, the LMS in-

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struction is used only once, at the beginning of the display list. It may sometimes be necessary to use a second LMS instruction. The need arises when the screen-memory area crosses a 4 K-byte boundary. (The memory-scan counter is only 12 bits wide, which is why it cannot cross a 4 K boundary.) In this case, an LMS instruction must be used to jump the memory-scan counter over the boundary. This means that display data are not fully relocatable. LMS instructions have wider uses that will be discussed later in this series.

Building Display Lists

Every display list should begin with three "blank-eight-lines" instructions. This defeats vertical overscan by bringing the beginning of the useful display 24 scan lines down. After this is done, the first display line should be specified. Simultaneously, the LMS should be used to tell ANTIC where it will find the screen memory. Then follows the actual display list, which lists the display bytes for the mode lines on the screen. The total number of horizontal scan lines produced by the display list should *always* be 192 or less; ANTIC does not maintain the screen-timing requirements of the television. If you give ANTIC too many scan lines to display, it will do so, but the television screen will probably roll. Displaying fewer than 192 scan lines causes no problems; indeed, it decreases 6502 execution time by reducing the number of cycles stolen by ANTIC. The programmer must calculate the sum of the horizontal scan lines produced by his or her display list and verify it. The display list must end with a JVB instruction.

A typical display list for a standard BASIC graphics mode 0 display (all values are in hexadecimal) is given in table 3. As you can see, this display list is short—only 32 bytes. Most display lists are less than 100 bytes long. Furthermore, they are quite simple in structure and easy to set up.

To implement your own display list, you must first design the display

Hexadecimal Address	Hexadecimal Value	Meaning
7BE0	70	blank 8 lines
	70	blank 8 lines
	70	blank 8 lines
	42	display ANTIC mode 2 (BASIC mode 0)
	20	also, screen memory starts at 7C20
	7C	
	02	display one mode line of ANTIC mode 2
	02	
	02	
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	41	JVB instruction—wait for the vertical-
	E0	blank signal, then jump to the beginning
	7B	of the display list, which starts at $7BE0

Table 3: *The display list for a standard BASIC graphics mode 0 display.*

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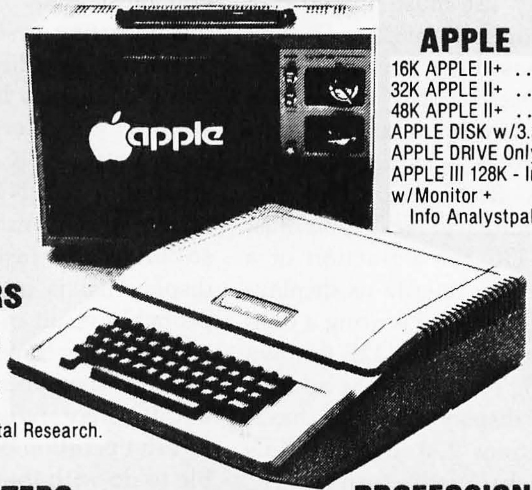

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format. This is best done on paper. Lay out the screen image and translate it into a sequence of mode lines. Keep track of the scan-line count of your display by looking up the scan-line requirements of the various modes in table 2. Translate the sequence of mode lines into a sequence of ANTIC mode bytes. Put 3 "blank-eight-lines" bytes (hexadecimal 70) at the top of the list. Set bit 6 of the first display byte (that is, make the upper nybble a 4)—this makes it a load-memory scan command. Follow with 2 bytes that specify the address of the screen RAM (low byte, then high). Then follow this with the rest of the display bytes. At the end of your display list, put in the JVB instruction (hexadecimal 41) and the address of the top of the display list. Store all these bytes into memory. They can be anywhere you want; just make sure they don't overlie something else, and be sure your JVB instruction at the end of the display list points to the top of the display list.

The display list must not cross a 1 K-byte address boundary. If you absolutely must have it cross such a boundary, insert a JMP instruction just in front of the boundary, with the JMP instruction's operand being the address of the first byte on the other side of the boundary. Next, you must turn off ANTIC for a fraction of a second while you rewrite its display-list pointer. Do this by writing a 0 into hexadecimal location 22F (known as SDMCTL). Then store the address of the new display list into hexadecimal locations 230 and 231 (low byte, then high). Lastly, turn ANTIC back on by depositing a hexadecimal 22 into SDMCTL. During the vertical blank, while ANTIC is quiet, the operating system will reload ANTIC's program counter with these new values.

Screen-Data Placement

Screen memory can be placed anywhere in the address space of the computer. Normally, the display list specifies the beginning of the screen memory with the first display instruction—the initial LMS instruction. However, ANTIC can execute a new LMS instruction with each display line of the display list, if this is desired. In this way, information from all over the address space of the computer can be displayed on a single screen. This can be of value in setting up independent text windows.

There are several restrictions in your placement of the screen memory. First, screen memory should not cross a 4 K-byte address boundary. If you cannot avoid crossing a 4 K-byte boundary (as would be the case in BASIC mode 8, which uses 8 K bytes of RAM), you must reload the memory-scan counter with a new LMS instruction. Second, if you wish to use any of the Atari operating-system screen routines, you must abide by the conventions the operating system uses. This can be particularly difficult when using a modified display list in a BASIC program. If you alter a standard display list from a BASIC program and then attempt to PRINT or PLOT to the screen, the operating system will do so under the assumption that the display list is unchanged. This will probably result in a garbled display.

Screen memory can be placed anywhere in the address space of the computer.

There are three ways the display can fail when you attempt this. First, BASIC may refuse to carry out a screen operation because it is impossible to do with the graphics mode that the operating system thinks it is in. The operating system stores the value of the graphics mode that it thinks is on the screen in hexadecimal address 57. You can fool the operating system into cooperating by POKEing a different BASIC mode value there. POKE the BASIC mode number, *not* the ANTIC mode number.

The second failure arises when you mix mode lines with different screen-memory byte requirements. Some mode lines require 40 bytes per line, some require 20 bytes per line, and some require only 10 bytes per line. Let's say that you insert one 20-byte mode line into a display list with 40-byte mode lines. Then you PRINT text to the display. Everything above the interloper line is fine, but below it the characters are shifted twenty spaces to the right. This is because the operating system assumed that each line would require 40 bytes and positioned the characters accordingly. But ANTIC, when it encountered the interloper line, took only 20 bytes of what the operating system thought should be a 40-byte line. ANTIC interpreted the other 20 bytes as belonging to the next line and displayed them there. This resulted in the next line and all later lines being shifted twenty spaces to the right.

The only absolute way around this problem is to refrain from using BASIC PRINT and PLOT statements to output to a mixed display-list screen. The quick and dirty solution is to organize the screen into line groups that contain integer multiples of the standard byte requirement. That is, do not insert a 20-byte mode line into a 40-byte display; instead, insert two 20-byte lines or one 20-byte line and two 10-byte lines. As long as you retain the proper integer multiples, the horizontal shift will be avoided.

This solution accentuates the third problem with mixed display lists and BASIC: vertical shifts. The operating system positions screen material vertically by calculating the number of bytes to skip down from the top of the screen. In a standard 40-byte line display, BASIC would position the characters onto the tenth line by skipping 360 bytes (40 bytes per line times 9 full lines) from the beginning. If you have inserted four 10-byte lines, BASIC ends up 3 lines further down the screen than you would otherwise expect. Furthermore, different mode lines consume different numbers of scan lines, so the position on the screen will not be quite what you expected if you do not take scan-line costs into account.

As you can see, mixed-mode displays can be difficult to use in conjunction with the operating system. Often, you must fool the operating system to make such displays work.

To PRINT or PLOT to a mode window, POKE the BASIC mode number of that window to hexadecimal location 57, then POKE the address of the top left pixel of the mode window into hexadecimal locations 58 and 59 (low byte, then high). In character modes, execute a POSITION 0,0 to home the cursor to the top left corner of the mode window. In map modes, all PLOTs and DRAWTOs will be made using the top left corner of the mode window as the origin of the coordinate system.

The display-list system can be used to produce appealing screen displays. Its most obvious use is for mixing text and graphics. For example, you could prepare a screen with a bold BASIC mode 2 title, a medium-size BASIC mode 1 subtitle, and small BASIC mode 0 fine print. You could then have a BASIC mode 8 picture in the middle, with more text at the bottom.

With assembly-language routines, modified display lists are best used by organizing the screen into a series of windows, each window having its own LMS instruction and its own independent RAM area.

Modification Applications

One simple application of display-list modifications is to vertically space lines on the screen by inserting blank-line bytes. This will add some vertical spacing, which will highlight critical messages and enhance the readability of some displays.

Another important use of display-list modifications is in providing access to features not available from BASIC. There are three text modes supported by ANTIC that BASIC does not support. You can gain access to these modes only by modifying the display list. There are also display-list-interrupt and fine-scrolling capabilities that are only available after the display list is modified. These features are the subjects of later articles in this series.

Manipulations with the LMS instruction and its operand offer many possibilities to the creative programmer. For example, by changing the LMS during vertical blank, the programmer can alternate screen images.

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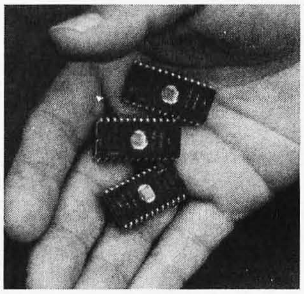

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	Pixel Contents (By Color Register)											
first frame	1	1	1	1	2	3	2	3	2	3	2	3
second frame	B	1	1	1	B	B	2	3	2	3	2	3
third frame	B	B	1	1	B	B	B	B	2	3	2	3
fourth frame	B	B	B	1	B	B	B	B	B	B	2	3
effective luminance × 4	2	4	6	8	10	12	20	24	30	36	40	48
perceived luminance												

Table 4: *Advanced color and luminance control through the high-speed changing of the video display; see the text for details.*

This can be done at slow speed to change between predrawn displays without having to redraw each one. Each display would continue to reside in (and consume) memory even while it is not in use, but it would be available almost instantly. This technique can also be used for animation. By flipping through a sequence of displays, cyclic animation can be achieved. The program to do this would manipulate only 2 address bytes to display thousands of bytes of memory.

It is also possible to superimpose images by flipping screens at high speed. The human eye has a time resolution of about $1/16$ of a second, so a program can cycle between four images, one every $1/60$ of a second, so each repeats every $1/15$ of a second. In this way, up to four images can appear to reside simultaneously on the screen. There are some drawbacks to this method. First, four separate displays may well cost a lot of memory. Second, each display image will be washed out because it only shows up one quarter of the time. This means that the background of all displays must be black, and each image must be bright. Furthermore, there will be some unpleasant screen flicker when this technique is used. A conservative programmer might consider cycling between only three or even two images. This technique can also be used to extend the color and luminance resolution of the computer. By cycling between four versions of the same image, each version stressing one color or luminance range, a wider range of colors and luminosities is available.

For example, suppose we wish to display a bar of many different luminances. We first set our four color registers to the following hexadecimal values:

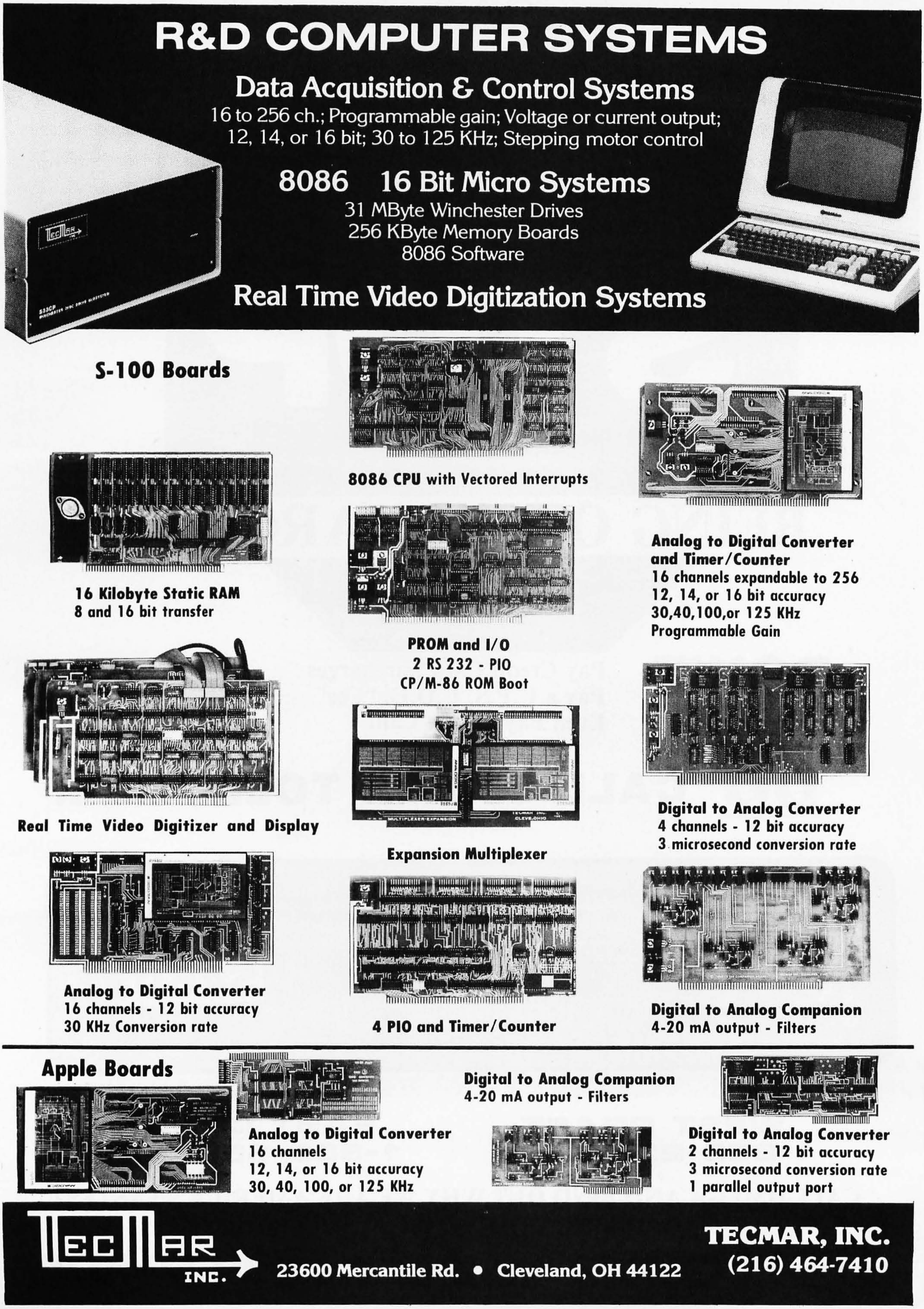
background:	00
playfield 1:	02
playfield 2:	0A
playfield 3:	0C

If we put the images described in table 4 into each of the screen-memory areas, we can achieve much finer luminance resolution.

A final suggestion concerns a subject that is laden with opportunities, but that is as little understood as the dynamic display list. This is a display list that the 6502 changes during vertical-blank periods. It should be possible to produce interesting effects with dynamic display lists. For example, a text-editing program could dynamically insert blank lines above and below the screen line being edited to set it apart from the other lines of text. As the cursor is moved vertically, the display list is changed to isolate the screen line the cursor is on. The technique is odd but very effective.

Conclusions

The display list is a powerful system for creating and controlling displays. It is not a simple system. In essence, it is a scheme for mating two completely different technologies, the television and the microcomputer. When I consider the differences between these two technologies and the exacting demands of each, I am surprised that the display-list system achieves such a favorable combination of power and simplicity. Even more surprising is the way the display-list system supports an even more powerful set of graphics capabilities, such as graphics indirection, display-list interrupts, and fine scrolling. These will be the subjects of future articles in this series. ■



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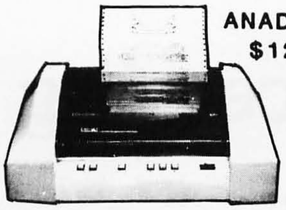

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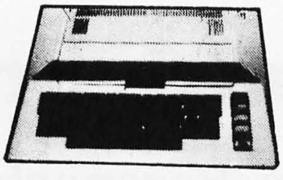

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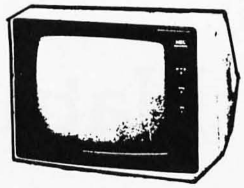

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The Field in Perspective

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Through a process spanning thousands of years, natural languages have evolved to meet the manifold needs of people to communicate and record a diversity of information in a wide variety of circumstances. Natural language is the medium of the butcher, the baker, and the candlestick maker; the poet and the lover; the politician and the preacher; the parent and the child. Even for the scientist and computer programmer, it is the mother tongue—the language resorted to when formal expressions and intuition fail.

Natural languages stand in marked contrast to formal languages, such as BASIC and Pascal, which were designed to be easily understood by computers and are intended for the specialized task of expressing algorithms and data structures. The fluent use of natural language is an information-processing activity of great complexity. Endowing computers with this ability has long been a major goal of research in *artificial intelligence* (also called *machine intelligence*), a branch of experimental computer science that studies the nature of knowledge and its manipulation.

Understanding the computational mechanisms that underlie the use of natural language is the central objective of *computational linguistics* (see the text box at the end of the article), a science at the juncture of artificial intelligence, philosophy, linguistics, and psychology. The two primary goals of this field are:

- to understand how humans communicate
- to create machines with human-like communication skills

The first is a scientific goal pursued to help us understand ourselves. In particular, although we all are implicitly expert in the *use* of natural language, we have only vague notions of the mental processes involved. A clearer insight into their essential nature and functioning might enable us to be better communicators, to train our children better in language skills, and even to design more efficient intercomputer communications.

The second goal is an engineering one pursued for a practical purpose—to create machines that can communicate with people in languages they already know. At present, only a small segment of the population, computer programmers, can communicate with computers. The advent of machines that understand natural languages will make it possible for virtually anyone to make direct use of powerful computational systems.

Progress in computational linguistics is facilitated by pursuing both of the above goals simultaneously. Creation of mechanical schemes for dealing with some aspect of natural-language processing sheds light on how it might actually be performed by the human brain. Similarly, evidence derived from observing how people use language suggests prospective computational mechanisms or, more often, provides valuable insights into the reasons particular mechanical processes fail.

To create computer systems that deal with certain significant subsets of natural-language phenomena, it is probably not necessary to perform the task in a way closely simulating computational processes in the human brain. This should not be surprising. Mechanical dishwashers use a nonhuman technique to produce a result equivalent to that of a human dishwasher. For interactions about very limited subject areas, we can hope to employ thoroughly nonhuman techniques in dealing with natural language. Nevertheless, machines concerned with any but the most mundane aspects of human language will probably have to deal with human psychology. After all, natural language has evolved as an efficient tool for conveying information between human minds. One of

the participants in a man-machine dialogue operates with all the constraints and richnesses of the human psyche; the other has to take these into account.

The ultimate goal of creating machines that can interact in a facile manner with people remains far off, awaiting both improved information-processing algorithms and alternative computing architectures. However, progress in the last decade has demonstrated the feasibility of employing today's computers to deal with natural-language input in highly restricted contexts. Futhermore, microcomputer implementation of these limited language-processing techniques is leading to more practical, cost-effective systems.

In this article, we offer an overview of the potential applications, experimental systems, existing techniques, research problems, and future prospects in this rapidly evolving field. We will address major issues in natural-language processing by focusing on several representative systems, necessarily leaving much important work unmentioned. For example, we will not discuss the complex issues involved in understanding spoken (as opposed to typed) language. Our intentions are to demonstrate that natural-language processing techniques are useful *now*, to reveal the richness of the computations performed by human natural-language communicators, and to explain why the fluent use of natural language by machines remains an elusive aspiration.

Applications of Natural-Language Processing

To motivate our discussion about how to approach the technological goal of creating a machine with human-like communication skills, let us consider some potential areas for the application of natural-language processing:

- *Machine translation*—The oldest dream of computational linguistics is of a mechanical device that can read documents written in one natural language and produce corresponding documents written in other languages, but with equivalent meanings. In fact, the birth of computational linguistics occurred in 1946, when Warren Weaver and A Donald Booth first suggested the use of a digital computer to create such a device. The Association for Computational Linguistics, the professional organization in this discipline, was originally named the Association for Machine Translation and Computational Linguistics.
- *Document understanding*—Beyond simply translating a document from one language to another, a device might read and *understand* documents, fitting their information into a larger framework of knowledge. A practical device of this sort would read and assimilate a document much as a person would. The device might subsequently produce abstractions of the document, alert people likely to be interested in it, or answer specific questions based on its information. If such a device had read many documents, it might be able to act as a librarian, directing users to pertinent references.
- *Document generation*—A task related to document understanding is document generation. We can envisage a device that translates information stored in a formal

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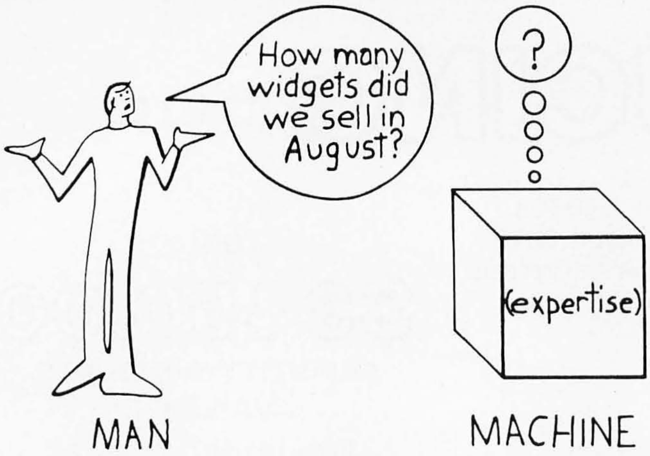

Figure 1: *The typical nontechnical user confronts a "black box" that contains large amounts of knowledge on a given subject.*

language in a computer's memory into ordinary language. For example, the designer of an automobile engine might describe repair procedures in a formal language. (After all, we expect that the designing of mechanical devices will someday be done principally by computer systems, which may *prefer* formal languages.) From this formal description, instruction manuals in various languages could be generated.

A more sophisticated system could generate special manuals for particular groups or individuals. Taking into account that mechanics know much about auto repair, a smart system would generate a different manual for mechanics than for automobile owners, but on the basis of the same underlying information. Information on elementary mechanical tasks would be included in manuals for less knowledgeable individuals. An ultimate system would tailor a manual to the background of each individual.

It is worth noting that a repair manual need not be written in linear sequence in a typical book format. Using a computer, advice about how to proceed on any particular problem could be dynamically generated to apply specifically to the task at hand. We will return to this topic later in the article.

• *As part of a system*—An interesting use of natural-language processing is as part of a larger computer-based system. For example, imagine devices that not only communicate in English, but also:

- provide answers to questions by accessing large data bases
- control complex equipment such as industrial robots, power generators, or missile systems
- furnish expert advice about medical problems, mechanical repairs, how to buy stocks, or what to cook for supper
- teach courses in a broad range of subjects

An extreme example of a computer-based system that would use natural-language processing as an integral component is a robot that communicates in English. Such a robot might be expected to perform as many tasks involving the use of natural language as might be done by a human assistant.

The importance of these potential applications and the basic science needed to make them possible has long been appreciated by scientific-funding agencies of the United States government. Current progress in the field is due largely to support from the Defense Advanced Research Projects Agency, the National Science Foundation, and the Office of Naval Research.

What Existing Systems Can Do

One of the most important and feasible areas for the application of natural-language processing is accessing data in data bases. Billions of dollars have been spent in collecting and encoding such data. However, this information is generally not readily available to the people who need it. The situation is illustrated by figure 1.

An executive in the widget business wants to direct a simple question to his black box. He wants to know, "How many widgets did we sell in August?" He knows the information is in the black box, but he lacks the expertise to make the box understand him.

As shown in figure 2, he must find an interpreter (computer programmer) who can translate his question into a formal query to give to the machine. Unfortunately, programmers are out drinking coffee when you need them,

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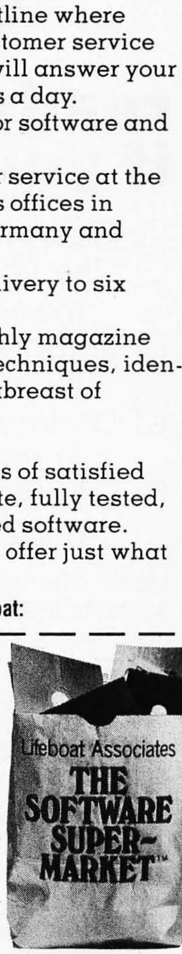

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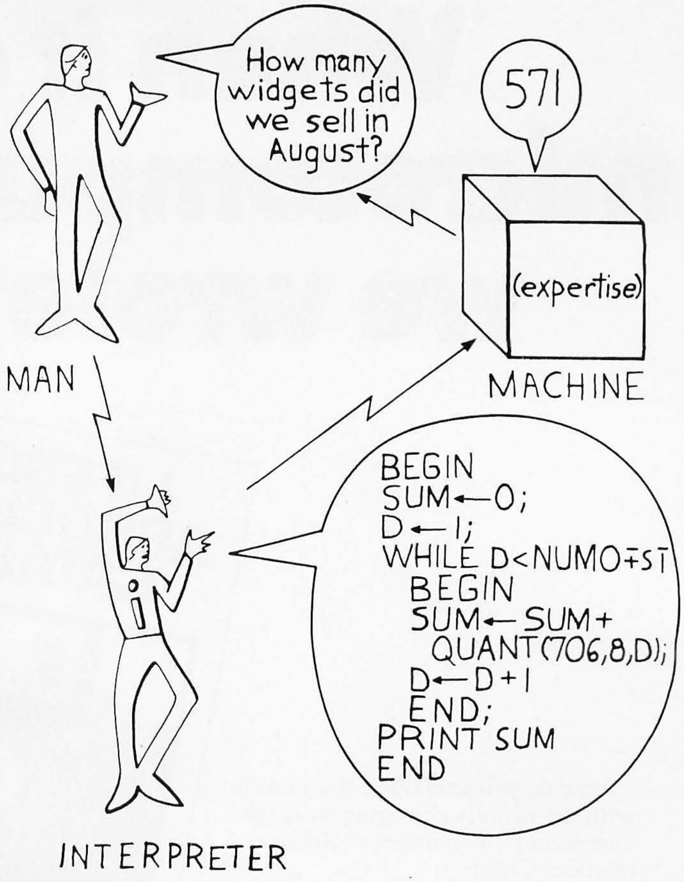

Figure 2: *The nontechnical user obtains information from the computer through the use of an interpreter (computer programmer), who translates the English question into a form the machine understands.*

or they are working on a project more important than your project—so they cannot help you this week. When a programmer *is* available, misunderstandings often occur and there are problems in creating proper code. By the time an answer is extracted from the computer, it may no longer be timely and may not even be relevant!

The LADDER System

To produce timely answers to questions and quickly clear up problems as to how a decision-maker's question is to be interpreted, the turnaround time must be cut from hours or days to seconds.

Research groups around the world are attempting to do this by automating the programmer in figure 2. For example, the LADDER system developed at SRI International (see references 11 and 12 at the end of this article) is capable of translating a question such as:

TO WHAT COUNTRY DOES
THE FASTEST SUB BELONG?

into either the code of listing 1 or listing 2, depending on which DBMS (data-base management system) has the relevant data. An explanation of these segments of code is unnecessary here. The point is that systems exist that are capable of accepting simple English queries specifying

Text continued on page 314

Listing 1: *An English-language query translated to an equivalent program in DATALANGUAGE.*

```
English Query—
  To what country does the fastest sub belong?
DATALANGUAGE Query—
  BEGIN
  DECLARE Y1 STRING (,100) ,D='}'
  DECLARE Y2 STRING (,100) ,D='}' Y2 = '00.0'
  DECLARE Y3 INTEGER Y3 = 0
  DECLARE Y5 STRING (,100) ,D='}' Y5 = 0
  DECLARE Y4 STRING (,100) ,D='}' Y4 = 0
  FOR R1 IN SHIPCLASCHAR WITH (R1.TYPE2 EQ 'S') AND
                                          (R1.TYPE1 EQ 'S')
    FOR R2 IN SHIPCLASDIR WITH (R2.SHIPCLAS EQ
    R1.SHIPCLAS)
      FOR R3 IN SHIP WITH (R3.UICVCN EQ R2.UICVCN)
        BEGIN
        Y1 = R3.MCSF
        IF Y1 LE '99.9' AND Y2 LT Y1 THEN
          BEGIN
          Y2 = Y1
          Y5 = R3.NAT
          Y4 = R3.NAM
          Y3 = 1
          END
        END
  IF Y3 EQ 1 THEN
    BEGIN
    NSTDPORT.STRING1 = Y4
    NSTDPORT.STRING2 = Y5
    END
  END
```


Listing 2: *An English-language query translated to an equivalent DBMS20 program.*

```
English Query—
        To what country does the fastest sub belong?
DBMS20 Query—
        COMPUTE XSTRX11 = '00.0' $
        COMPUTE XY10 = 0 $
        FIND FIRST SHIPCLASCHAR RECORD OF BLUEAREA
        AREA $
13      IF ERROR-STATUS = 307 GO TO 14 $
        COMPUTE XAND16 = 0 $
        IF SHIPCLASCHAR-TYPE2 NE 'S' GO TO 17 $
        COMPUTE XAND16 = 1 $
17      IF XAND16 = 0 GO TO 15 $
        COMPUTE XAND18 = 0 $
        IF SHIPCLASCHAR-TYPE1 NE 'S' GO TO 19 $
        COMPUTE XAND18 = 1 $
19      IF XAND18 = 0 GO TO 15 $
        COMPUTE XSTRZ12 = SHIPCLASCHAR-MCS $
        IF XSTRZ12 LT '00.0' OR XSTRX11 LE XSTRZ12 GO TO 15 $
        COMPUTE XSTRX11 = XSTRZ12 $
        COMPUTE XY10 = 1 $
        COMPUTE XSTR29 = SHIPCLASCHAR-MCS $
15      FIND NEXT SHIPCLASCHAR RECORD OF BLUEAREA
        AREA $
        GO TO 13 $
14      * $
        IF XY10 = 0 GO TO XT $
        FIND FIRST SHIPCLASCHAR RECORD OF BLUEAREA
        AREA $
20      IF ERROR-STATUS = 307 GO TO 21 $
        COMPUTE XAND23 = 0 $
        IF SHIPCLASCHAR-TYPE2 NE 'S' GO TO 24 $
        COMPUTE XAND23 = 1 $
24      IF XAND23 = 0 GO TO 22 $
        COMPUTE XAND25 = 0 $
        IF SHIPCLASCHAR-TYPE1 NE 'S' GO TO 26 $
        COMPUTE XAND25 = 1 $
26      IF XAND25 = 0 GO TO 22 $
        COMPUTE XAND27 = 0 $
        IF SHIPCLASCHAR-MCS NE XSTR29 GO TO 28 $
        COMPUTE XAND27 = 1 $
28      IF XAND27 = 0 GO TO 22 $
        FIND FIRST SHIPCLASDIR RECORD OF BLUEAREA AREA
        $
30      IF ERROR-STATUS = 307 GO TO 31 $
        COMPUTE XAND33 = 0 $
        IF SHIPCLASDIR-SHIPCLAS NE SHIPCLASCHAR-
        SHIPCLAS GO TO 34 $
        COMPUTE XAND33 = 1 $
34      IF XAND33 = 0 GO TO 32 $
        SET SHIP-UICVCN TO SHIPCLASDIR-UICVCN $
        FIND SHIP RECORD $
35      IF ERROR-STATUS = 326 GO TO 36 $
        PRINT SHIP-NAM SHIP-NAT $
37      FIND DUPLICATE SHIP RECORD $
        GO TO 35 $
36      * $
32      FIND NEXT SHIPCLASDIR RECORD OF BLUEAREA AREA $
        GO TO 30 $
31      * $
22      FIND NEXT SHIPCLASCHAR RECORD OF BLUEAREA
        AREA $
        GO TO 20 $
21      * $
        GO TO XT $
        END
```

Listing 3: *An actual conversation with the LADDER system. Boldface words represent user input. Material in square brackets replaces lengthy material not relevant to this article.*

```
1—Give me the length of the Kenedy.
                    spelling-> KENNEDY
PARSED!
Give the length of the ship KENNEDY JF

LEN = 1072
2—width and draft
PARSED!
Trying Ellipsis: GIVE ME WIDTH AND DRAFT OF THE KENEDY
Give the beam and draft of the ship KENNEDY JF
(BEAM 130 DFT 36)
3—Who is her commander?
Give the rank and name of the commander of the ship KENNEDY JF
(RANK CAPT NAME MOFFETT P)
4—What about the Fox?
PARSED!
Trying Ellipsis on: THE FOX
  WHO IS THE FOX COMMANDER
Give the rank and name of the commander of the ship FOX
(RANK CAPT NAME EVERETT J)
5—What U.S. merchant ships carrying vanadium ore are within 500
miles of the Kimlow?
PARSED!
Give the position of and time at position for the ship KIMLOW T
Give the name of merchant American ship S
  where the type of cargo on S is VNAD
    the great-circle distance from the position of S to
      15-33N, 30-10W, is less than or equal to 500
SHIP = GREENVILLE VICTORY, CRAIN ME, TOTOR
6—How fast are the U.S. subs with lengths greater than 150 feet?
PARSED!
Give the maximum cruising speed for and name of American ship S
  where the first character of the type of S is S
    the second character of the type of S is S
    the length of S is greater than 150
[A long table relating the names and maximum cruising speeds of
American submarines is printed.]
7—What French ships are at readiness status 1?
PARSED!
Give the name of French ship S
  where the state of readiness of S is 1

There is no French ship S
NONE
```

Text continued from page 310:

what information a user wants, then generating fairly complex programs specifying *how* the computer is to retrieve the information.

Two problems are being confronted together:

Problem 1: The system must translate from English into a formal language.

Problem 2: The system must convert a statement of what is wanted into a statement of how to get it.

Problem 2 is concerned with automatic programming, an artificial-intelligence problem currently receiving much attention (see reference 2). (Fortunately, most work on natural-language processing needs to consider only a highly restricted subset of this general problem.)

What it's like to use a system such as LADDER is suggested by the transcript, shown in listing 3, of an actual interaction. The system prompts users with a transaction number followed by a hyphen. The user then types in a question or command. (In this and future listings, we refer to the question half as a *query* and to the question/response pair as an *interaction*.) Query 1, "Give me the length of the Kenedy," contains a misspelled word. LADDER corrects this automatically, typing a note to the user directly below the input line. Once LADDER has corrected the spelling error and completed an analysis of the input, it types the message "PARSED!", and displays its interpretation of the user's query. The system then calls a remote data base to retrieve the answer—in this case, the length (abbreviated to LEN) of the *Kennedy* is 1072 (feet).

Query 2 is not a complete sentence. In fact, it makes no sense when considered in isolation. But in the context of the preceding query, it is clear that the intended meaning is, "Give me the width and draft of the Kennedy." Leaving out pieces of a sentence is called *ellipsis*. Processing such elliptical inputs is more difficult than it may seem. The system has to avoid such interpretations as, "Give me the length of the width and draft," or even, "Give width and draft the length of the Kennedy."

Query 3 illustrates the use of a pronoun, another linguistic construct that cannot be interpreted in isolation.

Query 4 demonstrates a more sophisticated form of ellipsis in which the analysis involves more than just grammatical substitution of the new input into the old one. (This is accomplished in LADDER by looking for "WHAT ABOUT" at the beginning of an input, and then applying the standard elliptical technique to what follows.)

Query 5 illustrates a major benefit of natural-language processing: the user can interact with the system in terms of the job being done, letting the system be concerned with what is required from the data base. Though this is only one question from the user's perspective, it requires two questions of the data base. First, the location of the *Kimlow* must be determined, and then the appropriate ships within 500 miles of that location must be retrieved. The process of translating from the user's terms to those of the data base obstructs the user's decision-making job. It is therefore an appropriate process to automate.

Interaction 6 causes a large body of information to be retrieved from the data base. Although omitted from the listing to save space, a table summarizing the answer is displayed to the user.

Interaction 7 shows an example of a cooperative response to the user's question. The user asks a question about the readiness of French ships. However, the data base contains no information about French ships. Therefore, the literal answer to the user's question, NONE, is inappropriate by itself, since it leads the user to believe all French ships are unready. To provide a more informative response, LADDER presents additional information showing the rationale for producing the NONE response.

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LADDER's methods for dealing with natural-language inputs are similar to those used by compilers and interpreters for such languages as BASIC and Pascal. For example, a BASIC interpreter might deal with assignment statements by looking for the pattern:

LET <variable> = <expression>.

This pattern could match an instruction of the form:

LET X = 5 + Y

with "X" filling the role of the <variable> and "5 + Y" filling the role of the <expression>. Associated with this pattern, the interpreter would have a function for storing the value of the expression into the memory location named by X.

Similarly, LADDER uses patterns such as:

WHAT <BE> THE <SHIP-ATTRIBUTES> OF <SHIP-DESCRIPTION>

that can match sentences such as:

WHAT ARE THE LENGTHS AND DRAFTS OF US CARRIERS?

Like an interpreter or compiler, LADDER associates a function with each pattern. The function associated with the example just cited would produce calls to the database management system to retrieve attributes of ships and take as parameters the names of the attributes and a description of the ships of interest. Most of LADDER's knowledge about language and the world is implicitly encoded in its grammar and associated functions. The grammar contains much information about the particular data base being queried and is by no means a standard grammar of English. A grammar of this type is called a *pragmatic* or *semantic grammar* (see references 4 and 11).

Summary of LADDER-Like Systems

In a later section, we will say more about what systems like LADDER can do. For now, it is sufficient to note the following:

- The computer capability shown in the transcript of listing 3 is of considerable practical utility.
- LADDER deals with a relatively large and complex data base that includes over 100 fields in fourteen files and has records for 40,000 ships.
- LADDER has been performing at this level of capability since 1976 (except for the cooperative responses such as those in interaction 7, which are relatively new—see reference 14).
- There are several systems in laboratories around the world that are capable of essentially the same level of performance as shown in listing 3. These include the systems described in references 10, 14, 24, 25, 26, and 31.

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Listing 4: *A dialogue between an expert and an apprentice repairman showing definitely determined noun phrases (underlined).*

A: HOW DO I REMOVE THE FLYWHEEL ?
E: FIRST LOOSEN THE TWO SMALL ALLEN HEAD SETSCREWS HOLDING IT TO THE SHAFT THEN PULL IT OFF.
A: THE TWO SETSCREWS ARE LOOSE BUT I'M HAVING TROUBLE GETTING THE WHEEL OFF.
E: USE THE WHEEL PULLER . DO YOU KNOW HOW?
A: NO
E: LOOSEN THE SCREW IN THE CENTER AND PLACE THE JAWS AROUND THE HUB OF THE WHEEL; THEN TIGHTEN THE SCREW.
A: THE LITTLE METAL SEMICIRCLE FELL OFF WHEN I TOOK THE WHEEL OFF.

For restricted classes of applications, systems such as LADDER provide language-processing capabilities that are very useful. Nevertheless, LADDER falls far short of being an ideal system, both conceptually and linguistically.

LADDER's concept of the world is based on the underlying conventional data-base management system to which it provides access. Data-base management systems can effectively store large numbers of individual, concrete facts, such as:

THE KENNEDY IS OWNED BY THE US

But they are incapable of dealing in a general way with more logically complex notions, such as disjunction, quantification, implication, causality, and possibility. They act as if they were dealing with information about a world containing a fixed number of objects and relationships among them, with the objects and relationships being immutable.

Perhaps LADDER's most important linguistic deficiency is its limited notion of linguistic context. With minor (though useful) exceptions, LADDER treats each input as if it were given in isolation. To perceive the problem, let's consider the question:

WHO ARE THE CAPTAINS OF THE US TANKERS?

Isolated from all contexts, this question should be interpreted as a request for the names of the commanding officers of all US tankers in the data base. But if a user has just asked the question, "What is the status of convoy C86? " and has received information on a number of ships in the convoy, including two US tankers, the sample question should elicit the captains' names for only the two tankers in the convoy. LADDER ignores the context, however, answering the question as if it had been asked in isolation.

The ability to follow a changing context and make accurate references to prominent objects is a fundamental characteristic of human communication. In fact, about half the words used in ordinary speech are found in DEF NPs (*definitely determined noun phrases*), the linguistic constructions most often used to refer to objects in context. Note, for example, all the definitely determined noun phrases underlined in the dialogue shown in listing 4.

The need to understand context throws considerable doubt on the idea of building natural-language interfaces to systems with knowledge bases independent of the language-processing system itself. This is because the information in the knowledge base may be needed simply for comprehension of a question. For example, to understand the phrase "the filter" in:

IF I CHANGE THE OIL IN MY CAR, WHERE SHOULD I LOOK FOR THE FILTER?

it is necessary to know that automobiles use oil cleaned by a filter. Such knowledge makes possible the assumption that such a filter, the one on the user's car, is the referent of "the filter." We cannot translate the question into a formal query to an auto-maintenance system unless the translation system also has some information about the nature of auto maintenance.

Systems for Dealing with Dynamic Microworlds

SHRDLU, a system developed by Terry Winograd at MIT around 1970 (see reference 29), was one of the first systems to deal with some of the complexities of context and address a domain of greater logical complexity than

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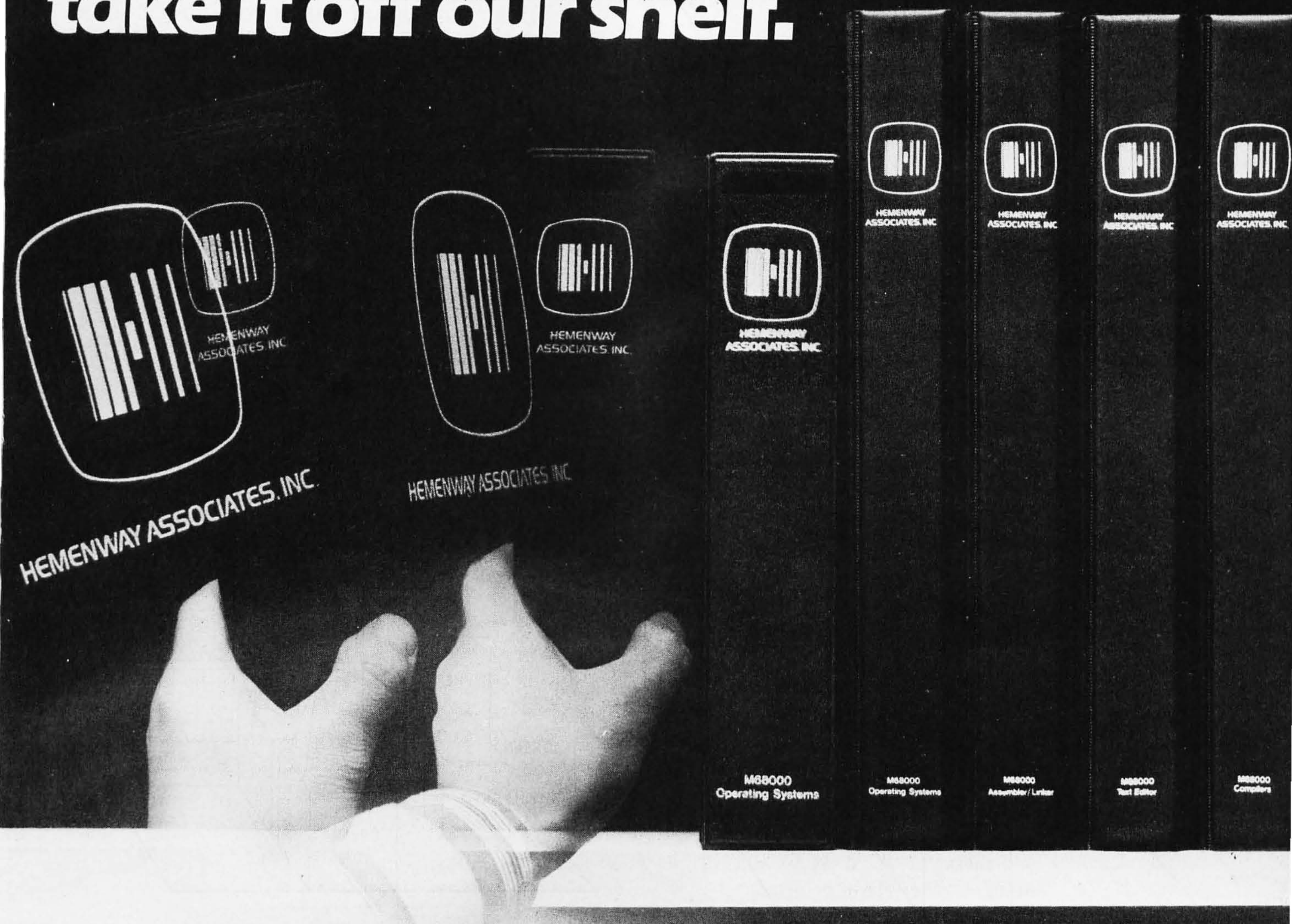

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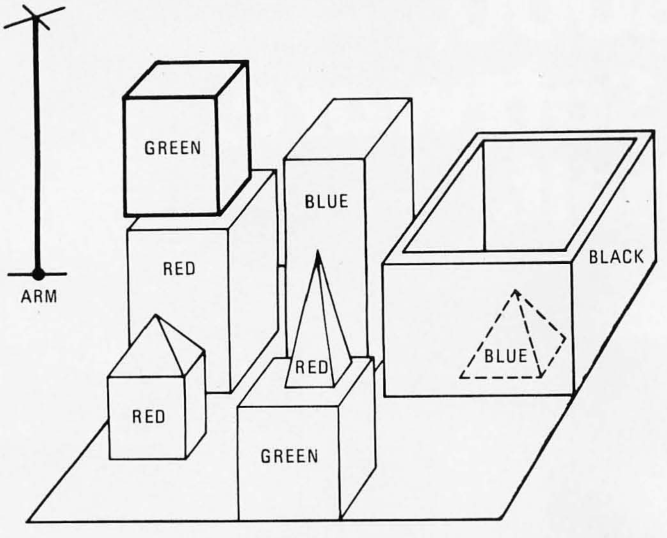


Figure 3: *The microworld of blocks used by the SHRDLU program, which can manipulate objects in the microworld and answer questions about them.*

Listing 5: *An actual conversation with the SHRDLU system. Associated images of the blocks microworld are given in figures 3, 4, and 5.*

1 — **PICK UP A BIG RED BLOCK.**
OK.
2 — **GRASP THE PYRAMID.**
I DON'T UNDERSTAND WHICH PYRAMID YOU MEAN.
3 — **FIND A BLOCK WHICH IS TALLER THAN THE ONE YOU ARE HOLDING AND PUT IT IN THE BOX.**
BY "IT" I ASSUME YOU MEAN THE BLOCK WHICH IS TALLER THAN THE ONE I AM HOLDING.
OK.
4 — **WHAT DOES THE BOX CONTAIN?**
THE BLUE PYRAMID AND THE BLUE BLOCK.
5 — **WHAT IS THE PYRAMID SUPPORTED BY?**
THE BOX.
6 — **HOW MANY BLOCKS ARE NOT IN THE BOX?**
FOUR OF THEM.
7 — **WHY DID YOU CLEAR OFF THE RED BLOCK?**
TO PICK IT UP.
8 — **WHY DID YOU DO THAT?**
BECAUSE YOU ASKED ME TO.

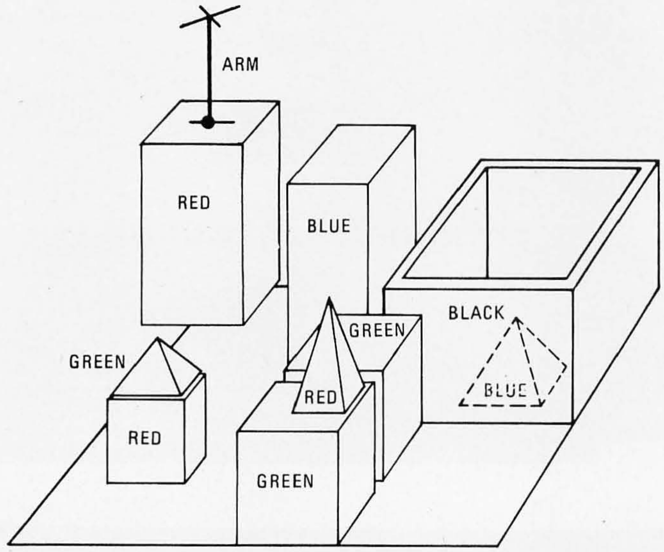


Figure 4: *SHRDLU in the process of executing the command "PICK UP A BIG RED BLOCK".*

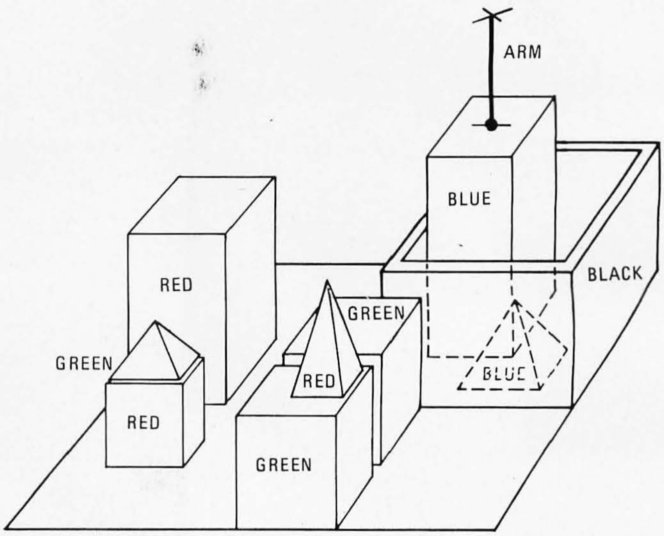


Figure 5: *The microworld after execution of the command "FIND A BLOCK WHICH IS TALLER THAN THE ONE YOU ARE HOLDING AND PUT IT IN THE BOX". (This takes place after the action of figure 4.)*

can be handled by a conventional data-base management system. An example of the types of interactions SHRDLU can support is shown in listing 5. At the beginning of the dialogue, both user and system are talking about a small microworld of blocks configured as shown in figure 3.

In interaction 1 of listing 5, SHRDLU is asked to pick up *a* big red block. Since there is only one such block in the microworld, SHRDLU knows what to pick up. Complicating the situation, however, is a green block resting on the big red block. SHRDLU is forced to devise a plan that involves moving the simulated robot arm to the green block, lifting the green block, moving the block to a clear place on the table, placing the green block on the table, releasing the green block, returning to the red block, grasping the red block, and, finally, lifting it up. When this is done (after considerable computation time), the microworld configuration is as shown in figure 4 and SHRDLU responds with a simple "OK".

In interaction 2, the user asks SHRDLU to grasp "the pyramid." But there are two pyramids in the microworld context, and the linguistic context contains no clues to choose between them. SHRDLU realizes that it cannot identify the referent of "the pyramid" and tells the user so.

Interaction 3 reveals SHRDLU's ability to deal with a fairly complex noun phrase containing a relative clause and a comparative construction, and to handle problematic words such as "one" and "it." The result of this

exchange is the microworld configuration shown in figure 5. Note that the system has found it necessary to put down the big red block it was holding.

Interaction 4 illustrates SHRDLU's question-answering ability. In the process of answering this question, the blue pyramid and blue block become the most salient objects in the linguistic context.

In interaction 5, the user again makes use of the phrase "the pyramid." SHRDLU is now able to assign a specific referent to the noun phrase. In particular, SHRDLU picks the pyramid most recently mentioned in the conversation.

In interaction 6, SHRDLU displays its ability to count and to handle negative constructions. Its response suggests a key limitation of SHRDLU—it assumes it knows everything there is to know about the microworld. In particular, it assumes it knows about all the blocks. To see how this simplifies things, ask yourself how many people (or blocks) are not in the room you are in.

Interactions 7 and 8 show SHRDLU's rudimentary ability to deal with references to actions, rather than just to simple objects, and to recall the history of previous actions and their causal linkage—essential skills for entering into conversations about dynamic worlds.

Limitations of SHRDLU

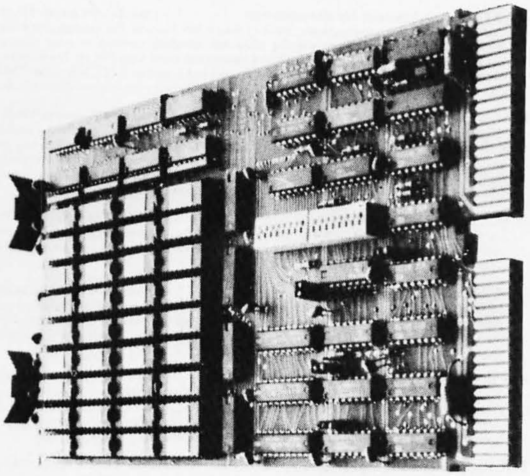
The sample SHRDLU dialogue illustrates the system's capacity to cope with dynamics in both the physical and linguistic environments.

As observed by Wilks (see reference 28), SHRDLU's apparent power derives largely from dealing with a logical, small, simple, closed microworld. The microworld is logical because all the facts about it can be stated in terms of first-order logic. This is fortunate because powerful problem-solving methods exist for dealing with bodies of facts in this form. But these powerful methods are computationally expensive and become increasingly inefficient as objects and facts proliferate and become more complex.

Fortunately for SHRDLU, its microworld contains fewer than a dozen objects, including the robot arm, and their interrelationships and the actions that can change those interrelationships are relatively simple. For example, there are no messy objects like pieces of rope or bodies of water that can assume an infinite variety of shapes or that can split or combine to form new objects. Furthermore, there are no cerebral creatures in the microworld to complicate the picture by having wants, goals, beliefs, and the like.

Finally, the microworld is closed because it is assumed to be completely knowable. If the box is empty and SHRDLU plans to put the blue block in it, there is no possibility that a gremlin will fill up the box with junk, turn it upside down, break it, nail a lid on it, or perform any of infinitely many activities. If SHRDLU wants to know if the box is empty, it simply tries to prove that it contains something, and watches to see if the proof fails. Anything in the microworld that is knowable is provable,

STATE OF THE ART MEMORY SYSTEMS



256KB LSI 11/23® SINGLE DUAL WIDTH BOARD

The First and Only 256KB Memory on a Single Dual Board.

4 MEGABYTE ADDRESS FIELD — Most memories available for the DEC PDP 11/23 are only addressable to 256K bytes (18 address lines). The CI-1123 is addressable to 4 mega bytes (22 address lines) so there is no need to worry about obsolescence.

FAST ACCESS AND CYCLE TIME — With an access time of 240 NSEC and cycle time of 400 NSEC one is insured the best throughput on the PDP 11/23 system.

PARITY — The CI-1123 generates and checks parity for each byte of memory. Totally DEC compatible.

BATTERY BACKUP POWER CONSUMPTION — Power requirement for the module is only 1.2 AMP from the 5 volt supply. The CI-1123 is easily configured for battery back-up mode of operation requiring only 300MA from a single 5 V back-up supply for 256KB memory in the down state.

SINGLE QTY. PRICE: 32K x 18 **$575.** 128K x 18 **$1925.**

512KB SINGLE BOARD MULTIBUS® MEMORY

State of the Art Multibus Memory Design.
First to Offer 512KB on One Board.

The CI-8086 module is compatible with both 8 or 16 bit Multibus Systems.

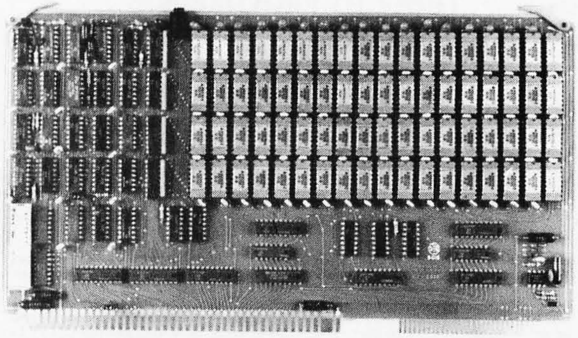
PARITY — The CI-8086 generates and checks even parity with selectable interrupt on parity error.

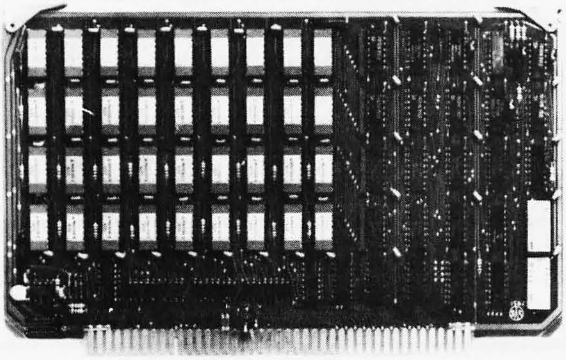
FAST ACCESS AND CYCLE TIME — Data access is 270 NSEC and cycle time is 375 NSEC.

16 MEGA BYTE ADDRESSING — The memory is addressable in 16K increments up to 16 mega bytes.

LOW POWER CONSUMPTION — Total power consumption is under 8 watts.

SINGLE QTY. PRICE: 128K x 9 **$1350.** 512K x 9 **$2995.**





64K x 9 EXORCISER® I SINGLE BOARD MEMORY

For Exorciser I, Exorciser II and Rockwell System 65.

FAST ACCESS AND CYCLE TIME — Data access time is 225 NSEC and cycle time is 400 NSEC, allowing the unit to work as a static RAM at clock rates in excess of 1.5 mega hertz. For 2 mega hertz operation the board can be easily configured to utilize a cycle stealing refresh operation.

ADDRESSING — On-board memory select is available in 4K increments up to 64K words of memory on either the VUA or VXA control inputs.

PARITY — On board even parity with output jumper select to the system bus as a parity error or non-maskable interrupt.

Complete board power consumption is under 7 watts.

SINGLE QTY. PRICE: 64K x 9 **$575.**

Tested and burned in. Full year warranty.

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Circle 61 on inquiry card.

DYNACOMP

Quality software for:*

ATARI — **TRS-80 (Level II)****
PET — **NORTH STAR**
APPLE II Plus — **CP/M Disks/Diskettes**

CARD GAMES

BRIDGE 2.0 (Available for all computers) — **Price: $17.95 Cassette/$21.95 Diskette**
An all-inclusive version of this most popular of card games. This program both BIDS and PLAYS either contract or duplicate bridge. Depending on the contract, your computer opponents will either play the offense OR defense. If you bid too high, the computer will double your contract! BRIDGE 2.0 provides challenging entertainment for advanced players and is an excellent learning tool for the bridge novice. See the software review in 80 Software Critique.

HEARTS 1.5 (Available for all computers) — **Price: $15.95 Cassette/$19.95 Diskette**
An exciting and entertaining computer version of this popular card game. Hearts is a trick-oriented game in which the purpose is not to take any hearts or the queen of spades. Play against two computer opponents who are armed with hard-to-beat playing strategies. HEARTS 1.5 is an ideal game for introducing the uninitiated (your spouse) to computers. See the software review in 80 Software Critique.

STUD POKER (Atari only) — **Price: $11.95 Cassette/$15.95 Diskette**
This is the classic gambler's card game. The computer deals the cards one at a time and you (and the computer) bet on what you see. The computer does not cheat and *usually* bets the odds. However, it sometimes bluffs! Also included is a five card draw poker betting practice program. This package will run on a 16K ATARI. Color, graphics, sound.

POKER PARTY (Available for all computers) — **Price: $17.95 Cassette/$21.95 Diskette**
POKER PARTY is a draw poker simulation based on the book, POKER, by Oswald Jacoby. This is the most comprehensive version available for microcomputers. The party consists of yourself and six other (computer) players. Each of these players (you will get to know them) has a different personality in the form of a varying propensity to bluff or fold under pressure. Practice with POKER PARTY before going to that expensive game tonight! Apple Cassette and diskette versions require a 32 K (or larger) Apple II.

CRIBBAGE 2.0 (TRS-80 only) — **Price: $14.95 Cassette/$18.95 Diskette**
This is simply the best cribbage game available. It is an excellent program for the cribbage player in search of a worthy opponent as well as for the novice wishing to improve his game. The graphics are superb and assembly language routines provide rapid execution. See the software review in 80 Software Critique.

THOUGHT PROVOKERS

MANAGEMENT SIMULATOR (Atari, North Star and CP/M only) — **Price: $19.95 Cassette $23.95 Diskette**
This program is both an excellent teaching tool as well as a stimulating intellectual game. Based upon similar games played at graduate business schools, each player or team controls a company which manufacturers three products. Each player attempts to outperform his competitors by setting selling prices, production volumes, marketing and design expenditures etc. The most successful firm is the one with the highest stock price when the simulation ends.

FLIGHT SIMULATOR (Available for all computers) — **Price: $17.95 Cassette/$21.95 Diskette**
A realistic and extensive mathematical simulation of take-off, flight and landing. The program utilizes aerodynamic equations and the characteristics of a real airfoil. You can practice instrument approaches and navigation using radials and compass headings. The more advanced flyer can also perform loops, half-rolls and similar aerobatic maneuvers. Although this program does not employ graphics, it is exciting and very addictive. See the software review in COMPUTRONICS.

VALDEZ (Available for all computers) — **Price: $15.95 Cassette/$19.95 Diskette**
VALDEZ is a computer simulation of supertanker navigation in the Prince William Sound/Valdez Narrows region of Alaska. Included in this simulation is a realistic and extensive 256 × 256 element map, portions of which may be viewed using the ship's alphanumeric radar display. The motion of the ship itself is accurately modelled mathematically. The simulation also contains a model for the tidal patterns in the region, as well as other traffic (outgoing tankers and drifting icebergs). Chart your course from the Gulf of Alaska to Valdez Harbor! See the software review in 80 Software Critique.

BACKGAMMON 2.0 (Atari, North Star and CP/M only) — **Price: $14.95 Cassette/$18.95 Diskette**
This program tests your backgammon skills and will also improve your game. A human can compete against a computer or against another human. The computer can even play itself. Either the human or the computer can double or generate dice rolls. Board positions can be created or saved for replay. BACKGAMMON 2.0 is played in accordance with the official rules of backgammon and is sure to provide many fascinating sessions of backgammon play.

CHECKERS 3.0 (PET only) — **Price: $16.95 Cassette/$20.95 Diskette**
This is one of the most challenging checkers programs available. It has 10 levels of play and allows the user to change skill levels at any time. Though providing a very tough game at level 4-8, CHECKERS 3.0 is practically unbeatable at levels 9 and 10.

CHESS MASTER (North Star and TRS-80 only) — **Price: $19.95 Cassette/$23.95 Diskette**
This complete and very powerful program provides five levels of play. It includes castling, en passant captures and the promotion of pawns. Additionally, the board may be preset before the start of play, permitting the examination of "book" plays. To maximize execution speed, the program is written in assembly language (by SOFTWARE SPECIALISTS of California). Full graphics are employed in the TRS-80 version, and two widths of alphanumeric display are provided to accommodate North Star users.

LEM LANDER (32K Apple Disk only) — **Price: $16.95 Diskette**
Pilot your LEM LANDER to a safe landing on any of nine different surfaces ranging from smooth to treacherous. The game paddles are used to control craft attitude and thrust. This is a real-time high res challenge!

FOREST FIRE! (Atari only) — **Price: $16.95 Cassette/$20.95 Diskette**
Using excellent graphics and sound effects, this simulation puts you in the middle of a forest fire. Your job is to direct operations to put out the fire while compensating for changes in wind, weather and terrain. Not protecting valuable structures can result in startling penalties. Life-like variables are provided to make FOREST FIRE! Very suspenseful and challenging. No two games have the same setting and there are 3 levels of difficulty.

NOMINOES JIGSAW (Atari, Apple and TRS-80 only) — **Price: $16.95 Cassette/$20.95 Diskette**
A jigsaw puzzle on your computer! Complete the puzzle by selecting your pieces from a table consisting of 60 different shapes. NOMINOES JIGSAW is a virtuoso programming effort. The graphics are superlative and the puzzle will challenge you with its three levels of difficulty. Scoring is based upon the number of guesses taken and by the difficulty of the board set-up.

MONARCH (Atari only) — **Price: $11.95 Cassette/$15.95 Diskette**
MONARCH is a fascinating economic simulation requiring you to survive an 8-year term as your nation's leader. You determine the amount of acreage devoted to industrial and agricultural use, how much food to distribute to the populace and how much should be spent on pollution control. You will find that all decisions involve a compromise and that it is not easy to make everyone happy.

CHOMP-OTHELLO (Atari only) — **Price: $11.95 Cassette/$15.95 Diskette**
CHOMP-OTHELLO? It's really two challenging games in one. CHOMP is similar in concept to NIM; you must bite off part of a cookie, but avoid taking the poisoned portion. OTHELLO is the popular board game set to fully utilize the Atari's graphics capability. It is also very hard to beat! This package will run on a 16K system.

DYNACOMP OFFERS THE FOLLOWING

- Widest variety
- Guaranteed quality
- Fastest delivery
- Friendly customer service
- Free catalog
- 24 hour order phone

AND MORE...

STARTREK 3.2 (Available for all computers) — **Price: $11.95 Cassette/$15.95 Diskette**
This is the classic Startrek simulation, but with several new features. For example, the Klingons now shoot at the Enterprise without warning while also attacking starbases in other quadrants. The Klingons also attack with both light and heavy cruisers and move when shot at! The situation is hectic when the Enterprise is besieged by three heavy cruisers and a starbase S.O.S. is received! The Klingons get even! See the software reviews in A.N.A.L.O.G., 80 Software Critique and Game Merchandising.

BLACK HOLE (Apple only) — **Price: $14.95 Cassette/$18.95 Diskette**
This is an exciting graphical simulation of the problems involved in closely observing a black hole with a space probe. The object is to enter and maintain, for a prescribed time, an orbit close to a small black hole. This is to be achieved without coming so near the anomaly that the tidal stress destroys the probe. Control of the craft is realistically simulated using side jets for rotation and main thrusters for acceleration. This program employs Hi-Res graphics and is educational as well as challenging.

SPACE TILT (Apple and Atari only) — **Price: $10.95 Cassette/$14.95 Diskette**
Use the game paddles to tilt the plane of the TV screen to "roll" a ball into a hole in the screen. Sound simple? Not when the hole gets smaller and smaller! A built-in timer allows you to measure your skill against others in this habit-forming action game.

MOVING MAZE (Apple only) — **Price: $10.95 Cassette/$14.95 Diskette**
MOVING MAZE employs the games paddles to direct a puck from one side of a maze to the other. However, the maze is dynamically (and randomly) built and is continually being modified. The objective is to cross the maze without touching (or being hit by) a wall. Scoring is by an elapsed time indicator, and three levels of play are provided.

ALPHA FIGHTER (Atari only) — **Price: $14.95 Cassette/$18.95 Diskette**
Two excellent graphics and action programs in one! ALPHA FIGHTER requires you to destroy the alien starships passing through your sector of the galaxy. ALPHA BASE is in the path of an alien UFO invasion; let five UFO's get by and the game ends. Both games require the joystick and get progressively more difficult the higher you score! ALPHA FIGHTER will run on 16K systems.

THE RINGS OF THE EMPIRE (Atari only) — **Price: $16.95 Cassette/$20.95 Diskette**
The empire has developed a new battle station protected by rotating rings of energy. Each time you blast through the rings and destroy the station, the empire develops a new station with more protective rings. This exciting game runs on 16K systems, employs extensive graphics and sound and can be played by one or two players.

INTRUDER ALERT (Atari only) — **Price: $16.95 Cassette/$20.95 Diskette**
This is a fast paced graphics game which places you in the middle of the "Dreadstar" having just stolen its plans. The droids have been alerted and are directed to destroy you at all costs. You must find and enter your ship to escape with the plans. Five levels of difficulty are provided. INTRUDER ALERT requires a joystick and will run on 16K systems.

GIANT SLALOM (Atari only) — **Price: $14.95 Cassette/$18.95 Diskette**
This real-time action game is guaranteed addictive! Use the joystick to control your path through slalom courses consisting of both open and closed gates. Choose from different levels of difficulty, race against other players or simply take practice runs against the clock. GIANT SLALOM will run on 16K systems.

TRIPLE BLOCKADE (Atari only) — **Price: $14.95 Cassette/$18.95 Diskette**
TRIPLE BLOCKADE is a two-to-three player graphics and sound action game. It is based on the classic video arcade game which millions have enjoyed. Using the Atari joysticks, the object is to direct your blockading line around the screen without running into your opponent(s). Although the concept is simple, the combined graphics and sound effect lead to "high anxiety".

GAMES PACK I (Available for all computers) — **Price: $10.95 Cassette/$14.95 Diskette**
GAMES PACK I contains the classic computer games of BLACKJACK, LUNAR LANDER, CRAPS, HORSERACE, SWITCH and more. These games have been combined into one large program for ease in loading. They are individually accessed by a convenient menu. This collection is worth the price just for the DYNACOMP version of BLACKJACK.

GAMES PACK II (Available for all computers) — **Price: $10.95 Cassette/$14.95 Diskette**
GAMES PACK II includes the games CRAZY EIGHTS, JOTTO, ACEY-DUCEY, LIFE, WUMPUS and others. As with GAMES PACK I, all the games are loaded as one program and are called from a menu. You will particularly enjoy DYNACOMP's version of CRAZY EIGHTS.

Why pay $7.95 or more per program when you can buy a DYNACOMP collection for just $10.95?

MOON PROBE (Atari and North Star only) — **Price: $11.95 Cassette/$15.95 Diskette**
This is an extremely challenging "lunar lander" program. The user must drop from orbit to land at a predetermined target on the moon's surface. You control the thrust and orientation of your craft plus direct the rate of descent and approach angle.

ADVENTURE

CRANSTON MANOR ADVENTURE (North Star and CP/M only) — **Price: $21.95 Diskette**
At last! A comprehensive Adventure game for North Star and CP/M systems. CRANSTON MANOR ADVENTURE takes you into mysterious CRANSTON MANOR where you attempt to gather fabulous treasures. Lurking in the manor are wild animals and robots who will not give up the treasures without a fight. The number of rooms is greater and the associated descriptions are much more elaborate than the current popular series of Adventure programs, making this game the top in its class. Play can be stopped at any time and the status stored on diskette.

ABOUT DYNACOMP

DYNACOMP is a leading distributor of small system software with sales spanning the world (currently in excess of 40 countries). During the past two years we have greatly enlarged the DYNACOMP product line, but have maintained and improved our high level of quality and customer support. The achievement in quality is apparent from our many repeat customers and the software reviews in such publications as COMPUTRONICS, 80 Software Critique and A.N.A.L.O.G. Our customer support is as close as your phone. It is always friendly. The staff is highly trained and always willing to discuss products or give advice.

**ATARI, PET, TRS-80, NORTHSTAR, CP/M and IBM are registered tradenames and/or trademarks.*

***TRS-80 diskettes are not supplied with DOS or BASIC.*

Circle 129 on inquiry card.

BUSINESS and UTILITIES

SPELLGUARD™ (CP/M only) Price: $269.95 Disk

SPELLGUARD is a revolutionary new product which increases the value of your current word processing system (WORDSTAR, MAGIC WAND, ELECTRIC PENCIL, TEXTED EDITOR II and others). Written entirely in assembly language, SPELLGUARD™ rapidly assists the user in eliminating spelling and typographical errors by comparing each word of the text against a dictionary (expandable) of over 20,000 of the most common English words. Words appearing in the text but not found in the dictionary are "flagged" for easy identification and correction. Most administrative staff familiar with word processing equipment will be able to use SPELLGUARD™ in only a few minutes.

MAIL LIST 2.2 (Apple, Atari and North Star diskette only) Price: $34.95

This program is unmatched in its ability to store a maximum number of addresses on one diskette (minimum of 1100 per diskette, more than 2200 for "double density" systems!). Its many features include alphabetic and zip code sorting, label printing, merging of files and a unique keyword seeking routine which retrieves entries by a virtually limitless selection of user defined codes. Mail List 2.2 will even find and delete duplicate entries. A very valuable program!

FORM LETTER SYSTEM (FLS) (Atari, Apple and North Star diskette only) Price: $21.95

Use FLS to create and edit form letters and address lists. Form letters are produced by automatically inserting each address into a predetermined portion of your letter. FLS is completely compatible with MAIL LIST 2.2, which may be used to manage your address files.

FLS and MAIL LIST 2.2 are available as a combined package for $49.95.

SORTIT (North Star only) Price: $29.95 Diskette

SORTIT is a general purpose sort program written in 8080 assembly language. This program will sort sequential data files generated by NORTH STAR BASIC. Primary and optional secondary keys may be numeric or one to nine character strings. SORTIT is easily used with files generated by DYNACOMP's MAIL LIST program and is very versatile in its capabilities for all other BASIC data file sorting.

PERSONAL FINANCE SYSTEM (Atari and North Star only) Price: $34.95 Diskette

PFS is a single diskette, menu-oriented system composed of ten different programs. Besides recording your expenses and tax deductible items, PFS will sort and summarize expenses by payee, and display information on expenditures by any of 26 user defined codes by month or by payee. PFS will even produce monthly bar graphs of your expenses by category! This powerful package requires only one disk drive, minimal memory (24K Atari, 32K North Star) and will store up to 600 records per disk (and over 1000 records per disk by making a few simple changes to the programs). You can record checks plus cash expenses so that you can finally see where your money goes and eliminate guesswork and tedious hand calculations.

FAMILY BUDGET (Apple only) Price: $34.95 Diskette

The FAMILY BUDGET is a very convenient financial record-keeping program. You will be able to keep track of cash and credit expenditures as well as income on a daily basis. You can record tax deductible items and charitable donations. The FAMILY BUDGET also provides a continuous record of all credit transactions. You can make daily cash and charge entries to any of 21 different expense accounts as well as to 5 payroll and tax accounts. Data is easily retrieved giving the user complete control over an otherwise complicated (and unorganized!) subject.

THE COMMUNICATOR (Atari only) Price: $49.95 Diskette

This software package contains a menu-driven collection of programs for facilitating efficient two-way communications through a full duplex modem (required for use). In one mode of operation you may connect to a data service (e.g., The SOURCE or MicroNet) and quickly load data such as stock quotations onto your diskette for later viewing. This greatly reduces "connect time" and thus the service charge. You may also record the complete contents of a communications session. Additionally, programs written in BASIC, FORTRAN, etc. may be built off-line using the support text editor and later "uploaded" to another computer, making the Atari a *very* smart terminal. Even Atari BASIC programs may be uploaded. Further, a command file may be built off-line and used later as controlling input for a time-share system. That is, you can set up your sequence of time-share commands and programs, and the Atari will transmit them as needed; batch processing. All this adds up to saving both connect time and your time.

DYNACOMP also supplies THE COMMUNICATOR with an Atari 830 modem for a combined price of $219.95. The modem is available separately for $189.95.

TEXT EDITOR II (CP/M) Price: $29.95 Diskette/$33.45 Disk

This is the second release version of DYNACOMP's popular TEXT EDITOR I and contains many new features. With TEXT EDITOR II you may build text files in chunks and assemble them for later display. Blocks of text may be appended, inserted or deleted. Files may be saved on disk/diskette in right justified/centered format to be later printed by either TEXT EDITOR II or the CP/M ED facility. Futher, ASCII CP/M files (including BASIC and assembly language programs) may be read by the editor and processed. In fact, text files can be built using ED and later formatted using TEXT EDITOR II. All in all, TEXT EDITOR II is an inexpensive, easy to use, but very flexible editing system.

DFILE (Atari and North Star only) Price: $19.95

This handy program allows North Star and Atari disk users to maintain a specialized data base of all files and programs in the stack of disks which invariably accumulates. DFILE is easy to set up and use. It will organize your disks to provide efficient locating of the desired file or program.

FINDIT (North Star only) Price: $19.95

This is a three-in-one program which maintains information accessible by keywords of three types: Personal (eg: last name), Commercial (eg: plumbers) and Reference (eg: magazine articles, record albums, etc). In addition to keyword searches, there are birthday, anniversary and appointment searches for the personal records and appointment searches for the commercial records. Reference records are accessed by a single keyword or by cross-referencing two or three keywords.

GRAFIX (TRS-80 only) Price: $14.95 Cassette/$18.95 Diskette

This unique program allows you to easily create graphics directly from the keyboard. You "draw" your figure using the program's extensive cursor controls. Once the figure is made, it is automatically appended to your BASIC program as a string variable. Draw a "happy face", call it H$ and then print it from your program using PRINT H$! This is a very easy way to create and save graphics.

EDUCATION

HODGE PODGE (Apple only, 48K Applesoft or Integer BASIC) Price: $19.95 Cassette/$23.95 Diskette

Let HODGE PODGE be your child's baby sitter. Pressing any key on your Apple will result in a different and intriguing "happening" related to the letter or number of the chosen key. The program's graphics, color and sound are a delight for children from ages 1½ to 9. HODGE PODGE is a non-intimidating teaching device which brings a new dimension to the use of computers in education.

TEACHER'S PET I (Available for all computers) Price: $11.95 Cassette/$15.95 Diskette

This is the first of DYNACOMP's educational packages. Primarily intended for pre-school to grade 3, TEACHER'S PET provides the young student with counting practice, letter-word recognition and three levels of math skill exercises.

MORSE CODE TRAINER (TRS-80 only) Price: $12.95 Cassette/$16.95 Diskette

MORSE CODE TRAINER is designed to develop and improve your speed and accuracy in deciphering Morse Code. As such, MCT is an ideal software package for FCC test practice. The code sound is obtained through the earphone jack of any standard cassette recorder. You may choose the pitch of the tones as well as the word rate. Also, various modes of operation are available including number, punctuation and alphabet tests, as well as the keying of your own message. A very effective way to learn code!

MISCELLANEOUS

CRYSTALS (Atari only) Price: $ 9.95 Cassette/$13.95 Diskette

A unique algorithm randomly produces fascinating graphics displays accompanied with tones which vary as the patterns are built. No two patterns are the same, and the combined effect of the sound and graphics are mesmerizing. CRYSTALS has been used in local stores to demonstrate the sound and color features of the Atari.

NORTH STAR SOFTWARE EXCHANGE (NSSE) LIBRARY

DYNACOMP now distributes the 23 volume NSSE library. These diskettes each contain many programs and offer an outstanding value for the purchase price. They should be part of every North Star user's collection. Call or write DYNACOMP for details regarding the contents of the NSSE collection.

Price: $9.95 each/$7.95 each (4 or more)
The complete collection may be purchased for $149.95

AVAILABILITY

DYNACOMP software is supplied with complete documentation containing clear explanations and examples. Unless otherwise specified, all programs will run within 16K program memory space (ATARI requires 24K). Except where noted, programs are available on ATARI, PET, TRS-80 (Level II) and Apple (Applesoft) cassette and diskette as well as North Star single density (double density compatible) diskette. Additionally, most programs can be obtained on standard (IBM format) 8" CP/M floppy disks for systems running under MBASIC.

STATISTICS and ENGINEERING

DIGITAL FILTER (Available for all computers) Price: $29.95 Cassette/$33.95 Diskette

DIGITAL FILTER is a comprehensive data processing program which permits the user to design his own filter function or choose from a menu of filter forms. The filter forms are subsequently converted into non-recursive convolution coefficients which permit rapid data processing. In the explicit design mode the shape of the frequency transfer function is specified by directly entering points along the desired filter curve. In the menu mode, ideal low pass, high pass and bandpass filters may be approximated to varying degrees according to the number of points used in the calculation. These filters may optionally also be smoothed with a Hanning function. In addition, multi-stage Butterworth filters may be selected. Features of DIGITAL FILTER include plotting of the data before and after filtering, as well as display of the chosen filter functions. Also included are convenient data storage, retrieval and editing procedures.

DATA SMOOTHER (Not available for Atari) Price: $14.95 Cassette/$18.95 Diskette

This special data smoothing program may be used to rapidly derive useful information from noisy business and engineering data which are equally spaced. The software features choice in degree and range of fit, as well as smoothed first and second derivative calculation. Also included is automatic plotting of the input data and smoothed results.

FOURIER ANALYZER (Available for all computers) Price: $16.95 Cassette/$20.95 Diskette

Use this program to examine the frequency spectra of limited duration signals. The program features automatic scaling and plotting of the input data and results. Practical applications include the analysis of complicated patterns in such fields as electronics, communications and business.

TFA (Transfer Function Analyzer) Price: $19.95 Cassette/$23.95 Diskette

This is a special software package which may be used to evaluate the transfer functions of systems such as hi-fi amplifiers and filters by examining their response to pulsed inputs. TFA is a major modification of FOURIER ANALYZER and contains an engineering-oriented decibel versus log-frequency plot as well as data editing features. Whereas FOURIER ANALYZER is designed for educational and scientific use, TFA is an engineering tool. Available for all computers.

HARMONIC ANALYZER (Available for all computers) Price: $24.95 Cassette/$28.95 Diskette

HARMONIC ANALYZER was designed for the spectrum analysis of repetitive waveforms. Features include data file generation, editing and storage/retrieval as well as data and spectrum plotting. One particularly unique facility is that the input data need not be equally spaced or in order. The original data is sorted and a cubic spline interpolation is used to create the data file required by the FFT algorithm.

FOURIER ANALYZER, TFA and HARMONIC ANALYZER may be purchased together for a combined price of $49.95 (three cassettes) and $59.95 (three diskettes).

REGRESSION I (Available for all computers) Price: $19.95 Cassette/$23.95 Diskette

REGRESSION I is a unique and exceptionally versatile one-dimensional least squares "polynomial" curve fitting program. Features include very high accuracy; an automatic degree determination option; an extensive internal library of fitting functions; data editing; automatic data and curve plotting; a statistical analysis (eg: standard deviation, correlation coefficient, etc.) and much more. In addition, new fits may be tried without reentering the data. REGRESSION I is certainly the cornerstone program in any data analysis software library.

REGRESSION II (PARAFIT) (Available for all computers) Price: $19.95 Cassette/$23.95 Diskette

PARAFIT is designed to handle those cases in which the parameters are imbedded (possibly nonlinearly) in the fitting function. The user simply inserts the functional form, including the parameters (A(1), A(2), etc.) as one or more BASIC statement lines. Data and results may be manipulated and plotted as with REGRESSION I. Use REGRESSION I for polynomial fitting, and PARAFIT for those complicated functions.

MULTILINEAR REGRESSION (MLR) (Available for all computers) Price: $24.95 Cassette/$28.95 Diskette

MLR is a professional software package for analyzing data sets containing two or more linearly independent variables. Besides performing the basic regression calculation, this program also provides easy to use data entry, storage, retrieval and editing functions. In addition, the user may interrogate the solution by supplying values for the independent variables. The number of variables and data size is limited only by the available memory.

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1. Customer goes to restaurant
2. Customer goes to table
3. Server brings menu
4. Customer orders food
5. Server brings food
6. Customer eats food
7. Server brings check
8. Customer leaves tip for server
9. Customer gives payment to cashier
10. Customer leaves restaurant

Table 1: *A restaurant script for the SAM program.*

and, therefore, anything that cannot be proved must be false.

The world that people deal with in everyday conversations is extensive, complex, and largely unknown and unknowable. To use natural language to converse about the real world, more sophisticated methods are needed.

Systems with Knowledge of Ordinary Situations

One of the more interesting attempts to deal with ordinary human situations, in contrast to interfacing with a data base or a model of a microworld, was made by Roger Schank and Robert Abelson, aided by their students at Yale University. Their system, SAM (for Script Applier Mechanism), as described in reference 22, was built to cope with certain kinds of everyday problems. For example, the system is told the following story:

John went to a restaurant.
He ordered the lamb.
He paid the cashier and
left the restaurant.

Then the system is asked:

What did John eat?

It might seem trivial for a system to answer that John ate the lamb—but nowhere in the story is this explicitly stated. Nor is it directly deducible from what was said. To understand the story, the system must have both knowledge of what usually happens in restaurants and an ability to apply that knowledge to particular situations.

Schank and Abelson encoded SAM's knowledge about everyday situations in formal constructs called *scripts*. The information contained in a script about restaurants is shown in table 1. It includes a list of players who participate in the normal routine of a restaurant, a list of props supporting the action, and a sequence of generic actions that characterize what usually happens when a customer visits a restaurant.

The information in this script can be used to support a variety of commonsense-reasoning tasks, including a reply to the question, "What did John eat?" The processing is as follows: the system identifies "John went to a restaurant" with action 1 from the script. In doing this, John is assigned the role of the customer. The system identifies "He ordered the lamb" with action 4, assigning the role of food to "the lamb." (Notice that with "he" referring to John, the customer is the same in both actions 1 and 4.) "He paid the cashier" is identified with action 9 and "[he] left the restaurant" with action 10.

Although not all the actions in the script were explicitly mentioned, it is reasonable (but not strictly necessary) to assume that they happened nonetheless. In particular, action 6, the customer eating the food, probably did happen. Moreover, because the entities playing the various parts in the script remain constant throughout its enactment, the system assumes that, for this particular visit to the restaurant, the customer in each action is John and the food is "the lamb." Therefore, action 6 particularizes to "John ate the lamb," providing the answer to the original question.

Information in scripts can be used for more than just answering questions; it can also be used to produce "paraphrases" of a story. For example, SAM can convert the original story:

John went to a restaurant. He sat down. He got mad.
He left.

into the "paraphrase":

John was hungry. He decided to go to a restaurant. He went to one. He sat down in a chair. A waiter did not

go to the table. John became upset. He decided he was going to leave the restaurant. He left it.

This restatement is not a true paraphrase because it adds many details based on speculation about what happened. But such an ability to speculate on the basis of knowledge about how our everyday world is structured is the very feature that makes SAM interesting.

Much of SAM's knowledge is not about natural language at all, but about our everyday world. SAM demonstrates that understanding natural-language stories about mundane actions requires more than a knowledge of language—it requires a knowledge of the world. The more language is studied, the more apparent it becomes that fluent communication in natural language is a process of the total intellect. Language, thought, and knowledge are inextricably intertwined.

Limitations of SAM

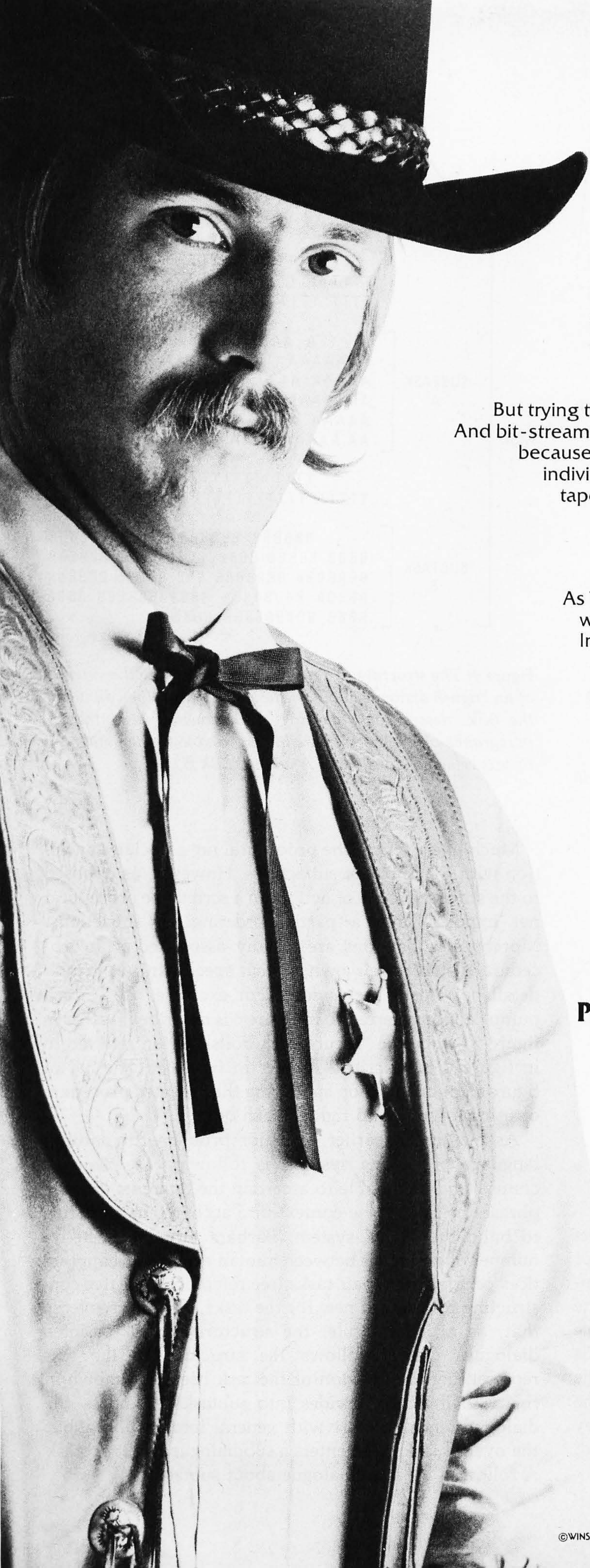
SAM's scripts provided one of the first mechanisms in a language processor for dealing with the *structured* sequences of actions that make up much of ordinary life, but they suffer from a number of limitations:

- Only a single object can serve the role of player or prop. This makes it impossible to handle stories about restaurants with many tables, customers, or servers. The problem of figuring out what the phrase "the customer" refers to becomes trivial because there can be only one customer.
- The actions in a script follow a strict linear sequence, making it impossible to deal with alternative possibilities, simultaneous or overlapping actions, or a repetition of actions.
- It is difficult to determine which particular script or scripts are appropriate for understanding a given story.

The TDUS System

The SHRDLU example discussed earlier suggested the potential richness of interactive dialogue in context. The SAM example showed how inference (ie: filling in the blanks regarding what was implied, as well as what was explicitly stated) is essential in understanding natural language. To determine how knowledge-based inference and dialogue management interact, as well as work toward solving a problem of practical value, a group of researchers at SRI International investigated cooperative, task-oriented, man-machine dialogue (see reference 19). They developed a system called TDUS (Task-Oriented Dialogue Understanding System), which had the goal of communicating with a human apprentice about repair operations on electromechanical equipment. The key research problems considered concerned how to encode knowledge about the repair operations and how to follow the context of a dialogue as the apprentice moved from task to task in the course of performing a repair operation.

In TDUS, information about how various tasks can be performed is recorded in data structures called *procedural networks* (see reference 21), which can be viewed



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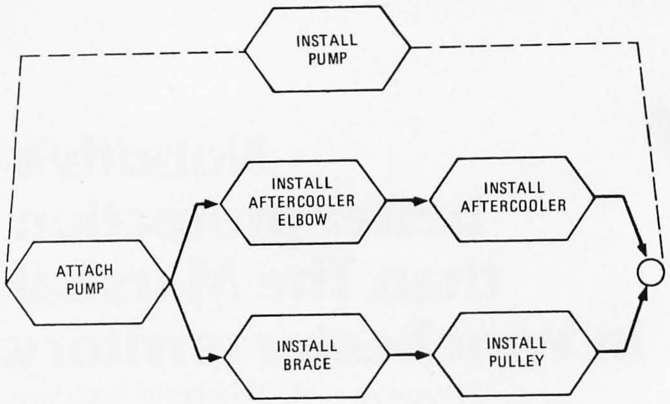

Figure 6: *A procedural net for the process of installing a pump for an air compressor.*

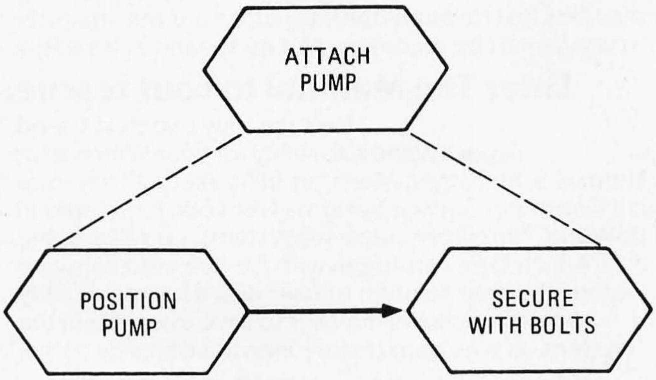

Figure 7: *A procedural net expanding an action referenced in figure 6.*

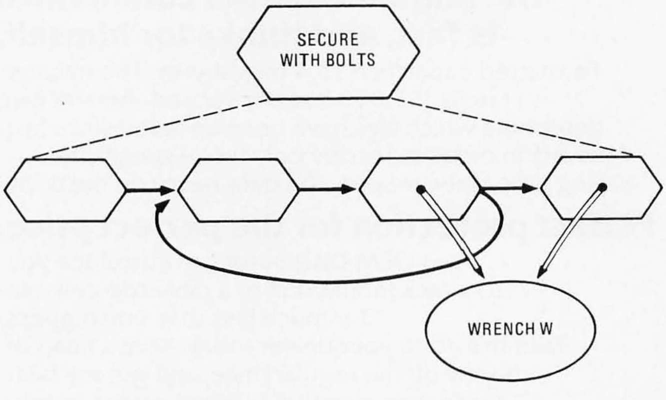

Figure 8: *A procedural net that contains actions repeated in a loop.*

as generalizations of scripts. Simplified procedural nets are shown in figures 6, 7, and 8. For example, the net of figure 6 indicates how installing a pump for an air compressor can be divided into a number of subtasks. The first subtask is to attach the pump to the platform. Once this is done, either the aftercooler elbow or the brace is installed. Once the aftercooler elbow is installed, the aftercooler is installed. Once the brace is installed, the pulley is installed. When both the aftercooler and pulley have been installed, regardless of the order accomplished, the task of installing the pump is complete.

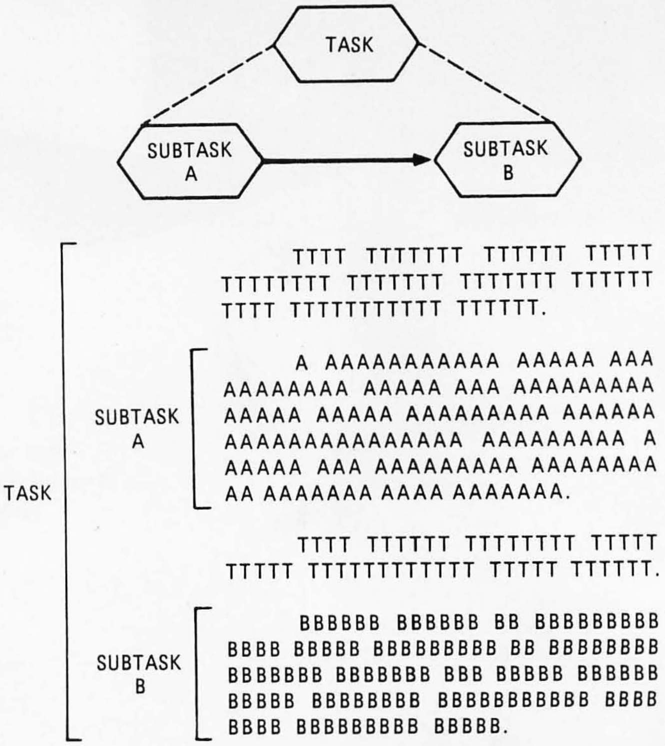

Figure 9: *The structure of a task (top) is reflected in the structure of an English dialogue about the task (bottom). When discussing the task, descriptions referring to the overall task (the two paragraphs of the letter T) are interspersed with the paragraphs of text referring to subtask A and subtask B.*

Much like a script, the procedural net associates an action with a number of subactions. However, as opposed to the strict sequence of actions in a script, the procedural net imposes only a partial ordering on subactions. Moreover, subactions are usually associated with procedural nets of their own, which specify in yet greater detail how tasks are divided. For example, the "attach pump" action referred to in figure 6 is described further in figure 7, while the "secure with bolts" action referred to in figure 7 is described further in figure 8. The net of figure 8 contains a loop specifying the repeated procedure of using a wrench to tighten each bolt.

As mentioned earlier, a major problem for natural-language processing systems is following the dialogue context and being able to ascertain the referents of noun phrases by taking the context into account. In preparing to build the TDUS system, Barbara Grosz collected a number of dialogues between human experts and apprentices performing repair tasks (see reference 8). After constructing procedural nets for the tasks, it was discovered that, as a general rule, the structure of task-oriented dialogues closely follows the structure of the nets representing the division of the task itself. As shown in figure 9, if a task divides into subtasks A and B, the dialogue tends to start with general information about the overall task, then enters a subdialogue about subtask A followed by a subdialogue about subtask B.

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Of greater interest is the fact that referential expressions tend to refer to objects salient in the current subtask or higher in the task hierarchy, but generally do not refer to objects in sibling subtasks. For example, if in the dialogue of figure 9 a wrench W_1 is mentioned in one of the initial utterances before entering subdialogue A, and if a second wrench W_2 is mentioned within subdialogue A, the phrase "the wrench" uttered in subdialogue B more likely refers to W_1 than to W_2—even though W_2 was mentioned more recently. (This is clearly in violation of the rule used by SHRDLU in interaction 5 of listing 3.) In this regard, referential expressions in natural languages tend to follow much the same conventions as do variable references in block-structured programming languages such as ALGOL and Pascal. But the block structure of natural language is not indicated explicitly.

TDUS's ability to follow real-world tasks and deal with shifts in both the linguistic and physical context is illustrated in the transcript of listing 6, which relates to information contained in the nets of figures 6 through 8.

In interaction 1, the apprentice sets the stage by specifying what action is being done. This allows TDUS to pinpoint the location in the INSTALL-PUMP net where the apprentice appears to be. In interaction 2, the apprentice refers to a bolting action and a wrench used in that action. Neither of these is in the top-level representation of the ATTACH-PUMP net, but they both occur in the subordinate net of figure 8. TDUS finds this subnet and determines that no other relevant subnet refers to a different bolting action. Therefore, the system responds by specifying the wrench mentioned in the net shown in figure 8.

In interaction 3, the apprentice asks for the location of the bolts. TDUS does not operate under the closed-world assumption and realizes that there are some things it does not know. Luckily, the user finds the bolts in interaction 4.

In interaction 5, the apprentice refers to "the wrench." TDUS determines that the reference is to the wrench mentioned in interaction 2 and tells the apprentice its location. In interaction 6, TDUS resolves "it" as pertaining to the same object.

In interaction 7, the apprentice tells TDUS that the pump-attaching operation is completed. The system infers from this that all the constituent subtasks have also been done. To make sure, it reviews these assumptions for the apprentice. This filling in of intermediate steps is much like that in the SAM examples.

In interaction 8, the apprentice poses a logically complex question involving the modal concept *"should."* TDUS's rudimentary notion of "should" interprets the question as asking whether the action mentioned is com-

Listing 6: *An actual conversation with the TDUS system. With this system, the computer supervises a task performed by a human apprentice. Human input is shown in boldface.*

1 — **I AM ATTACHING THE PUMP.**
OK.
2 — **WHICH WRENCH SHOULD I USE TO BOLT IT?**
USE THE BOX-END WRENCH.
3 — **WHERE ARE THE BOLTS?**
I DON'T KNOW.
4 — **I FOUND THEM.**
OK.
5 — **WHERE IS THE WRENCH?**
THE BOX-END WRENCH IS ON THE TABLE.
6 — **I FOUND IT.**
OK.
7 — **I ATTACHED THE PUMP.**
OK.
THE FOLLOWING HAS BEEN ASSUMED:
YOU PUT THE PUMP AT THE PLATFORM. YOU BOLTED THE PUMP TO THE PLATFORM WITH THE BOLTS.
8 — **SHOULD I INSTALL THE PULLEY NOW?**
NO.
THE NEXT STEP IS:
INSTALL THE AFTERCOOLER ELBOW ON THE PUMP
OR
INSTALL THE BRACE ON THE PUMP.
9 — **I'M DOING THE BRACE NOW.**
OK.
"DO" IS ASSUMED TO MEAN:
YOU ARE INSTALLING THE BRACE.
10 — **I'VE DONE IT.**
OK.
"DO" IS ASSUMED TO MEAN:
YOU INSTALLED THE BRACE.
THE FOLLOWING HAS BEEN ASSUMED:
YOU PUT THE BRACE AT THE PUMP.
YOU SECURED THE BRACE.
11 — **I'VE INSTALLED THE PULLEY.**
OK.

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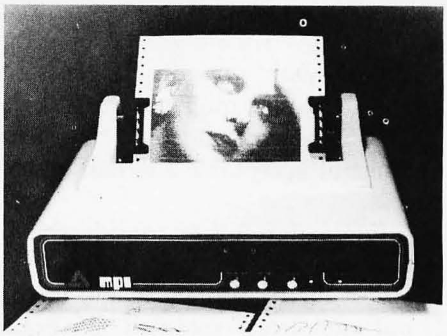

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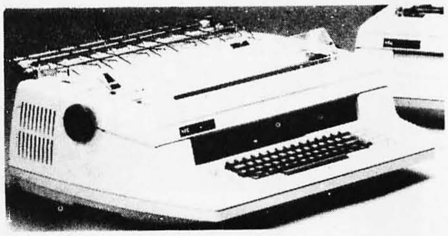

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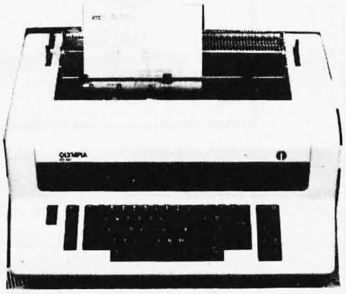

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patible with one of the possible next steps in the procedural-net model of the task at hand. Since it is not, TDUS answers in the negative, but goes on to outline the range of acceptable alternatives at this point in the process.

Interaction 9 is of considerable interest in that it contains the pro-verb "do." This is a reference to some action involving the apprentice and the brace. But the action is not completely specified. By examining the procedural net, TDUS determines that the likely thing to do with a brace in this context is to install it—so TDUS makes that assumption and reports it to the apprentice.

Interaction 10 demonstrates TDUS's ability to comprehend an extreme case of contextually dependent use of language. Neither "done" nor "it" conveys much information. Here, "it" refers not to some object in the world, but to an action previously alluded to by the phrase "doing the brace."

Limitations of TDUS

TDUS exhibits a reasonable understanding of the interplay among various types of possible real-world actions, and it can follow the evolution of particular instantiations of those actions. However, it has little understanding of the goals and motivations of the apprentice with whom it holds conversations.

An exchange well beyond the capability of TDUS is shown in the following actual dialogue between a novice and an expert mechanic:

1. **WHAT DO I DO NEXT?**
REMOVE THE BOLT.

2. **HOW DO I GET IT OFF?**
USE THE RATCHET WRENCH.

3. **WHAT'S A RATCHET WRENCH?**
IT'S ON THE TABLE.

Figure 10: *A sentence that conveys different information to different people.*

The key point to note here is that, in interaction 3, the response is not a *direct* answer to the question. If TDUS could answer this question at all, it would likely respond with a dictionary definition such as: "a tool for grasping and turning the head of a bolt, consisting of fixed or adjustable jaws mounted on a pawl that is engaged by the toothed end of a gripping bar." The person who answered query 3 understood the motivation behind the question. It was asked so the inquirer would know the description of a ratchet wrench, so he could find it, so he could grasp it, and so he could use it to remove the bolts. Understanding the inquirer's hierarchy of goals, the respondent addresses one of the goals closer to the end of the chain (finding the wrench). The cooperative respondent saves the inquirer the trouble of taking the step of locating the wrench from its description.

Beyond Current Systems

Researchers in computational linguistics have only recently begun to appreciate the impact on natural-language communication of what the participants in a conversation know about each other's knowledge, beliefs, plans, and goals. To appreciate the importance of such knowledge, consider the situation illustrated in figure 10.

A young mother is giving a birthday party for Junior, and Grandma has come to help. Grandma's task is to light the candles on the cake, so she asks, "When shall I light the candles?" The mother replies, "We'll have the cake as soon as the children wash their hands," which informs Grandma that it will be about five minutes. The mother knows that the big-eared kids are listening, so she phrases her response to serve multiple purposes for multiple audiences. With her one statement, she tells Grandma when the candles need to be lit and, in a nice, indirect way, tells the children to get their dirty hands washed. She knows that her response to Grandma will serve this purpose because she knows that:

- the children want the cake
- her response to Grandma will convey to them the information that all that stands in the way of their getting it is to wash their hands
- if they know that all that stands in the way of their getting cake is to wash their hands, they will perform the ritual forthwith
- it takes them about five minutes to wash their hands

Similarly, Grandma now knows that she should light the candles in five minutes because she knows that the mother knows all the circumstances just outlined and that the mother knows Grandma knows that the mother knows it. Thus, Grandma infers that the mother expects her to understand that the children are being told to wash their hands, that they are motivated to do it right away, and the result five minutes later will presumably be washed hands reaching avidly for cake.

No system is currently capable of handling language with this level of sophistication, but a number of researchers are actively engaged in studying the various problems involved; see references 3, 5, 6, 7, 13, 14, 16, 18, 23, and 27. Much of this work is concerned with the difficulties of interpreting not just what is literally said, but also of establishing the underlying intention. Should this work succeed, systems may be capable of the kind of reasoning indicated in listing 7.

The examples of the locked toolbox and the birthday party support a central point: communicating in natural language is an activity of the total intellect. Seen in broad perspective, the use of natural language can be placed in a general framework that seeks to account for all human activity. Within this framework, humans are seen as intelligent beings motivated by complex sets of goals they seek to fulfill by planning, executing, and monitoring sequences of actions—some of which are physical, some linguistic. That is, uttering a sentence is just as much an action as taking a step or taking a bath. Whereas the usual purpose of a physical action is to alter the physical world, the usual purpose of a linguistic action is to alter

Listing 7: *An imaginary conversation with a TDUS-like system showing the possible behavior of a computer system that reacts to human needs in a way not currently possible by existing systems.*

USER:	**THE TOOLBOX IS LOCKED.**
SYSTEM:	(WHY IS HE TELLING ME THIS? I ALREADY KNOW THE BOX IS LOCKED.)
	(I KNOW THE USER NEEDS TO GET IN. PERHAPS HE IS TELLING ME THE BOX IS LOCKED BECAUSE HE BELIEVES I CAN SOMEHOW HELP.)
	(TO GET IN TAKES A KEY. THE USER KNOWS THIS AND KNOWS I KNOW IT. THE KEY IS IN THE DRAWER. IF THE USER KNEW THIS HE WOULD JUST UNLOCK THE BOX. THEREFORE, HE MUST NOT KNOW IT.)
	(I CAN MAKE HIM COME TO KNOW IT BY SAYING "THE KEY IS IN THE DRAWER." I AM SUPPOSED TO HELP. I WILL SAY IT.)
	THE KEY IS IN THE DRAWER.

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the mental states of the hearers. In the latter case, the desired modification may be to add knowledge, change a mood, or establish a new goal for the hearers.

A speaker may plan and execute linguistic actions to change some aspect of a hearer's mental state, not as an end in itself, but as part of an overall plan to achieve some more ambitious end. Just as a child might push over the first domino of a long row to make them all tumble in sequence, a lifeguard at the beach may yell "Shark!" at swimmers to set off a chain of reasoning in their minds that will result in a mad dash for the shore, which is the lifeguard's intended mechanism for accomplishing the primary goal of preserving life.

Given this view of how language works, it becomes less important to ask what a given utterance means (what does "Shark!" mean?) and more important to ask about the effect it produces. People in advertising have an explicit understanding of this concept, but all of us use it implicitly when we understand the agony conveyed by the string of curses uttered by the handyman who smashes his finger, and when we realize that our friend's question, "Do you know the time?," deserves more than a "yes" or "no" answer.

The understanding of poetry can even be cast in this mold. The poet deliberately triggers certain chains of inference in readers. Indeed, an important element in the appreciation of poetry is the reader's awareness of the interplay among the inference chains followed, the chains followed partway that turn out to be not quite appropriate, and the surface meanings of the sentences comprising the poem itself. To experience this, just consider the title of T S Eliot's poem, "The Love Song of J. Alfred Prufrock."

The Nature of Natural-Language Research

The previous sections discussed the capabilities and limitations of specific natural-language processing systems. But it must be recognized that these systems are merely spin-offs of the underlying science. In essence, most researchers in this field do not think of themselves as engineers seeking to evolve better natural-language processing systems, but rather as scientists concerned with the following related problems:

- identification of sources of knowledge necessary for understanding or generating natural language
- discovery or devising of mechanisms for encoding and applying such knowledge in a mechanical device
- creation of integration frameworks to control and coordinate the application of a variety of knowledge sources

Once sources of knowledge have been identified, whole subdisciplines come into being to study the associated bodies of knowledge, their structure, and methods for their computerization. Some of the major knowledge sources are discussed below.

Lexical knowledge concerns individual words, the parts of speech they belong to, and their meanings.

Syntactic knowledge has to do with the grouping of words into meaningful phrases. For example, syntactic

knowledge distinguishes between the following two sentences:

NAME THE PARTS OF THE PUMP THAT *WAS* FIXED BY JOE.
NAME THE PARTS OF THE PUMP THAT *WERE* FIXED BY JOE.

In particular, it is the syntactic number distinction between WAS and WERE that indicates whether the pump or the parts were fixed.

Syntactic ambiguity is a common source of trouble in natural-language processing systems. For example, decisions about where to associate the prepositional phrase "on the table" in:

PUT THE HAMMER IN THE TOOLBOX ON THE TABLE.

can lead to any one of the interpretations:

PUT THE HAMMER THAT IS IN THE TOOLBOX ONTO THE TABLE.
PUT THE HAMMER INTO THE TOOLBOX THAT IS ON THE TABLE.
WHILE YOU STAND ON THE TABLE, PUT THE HAMMER INTO THE TOOLBOX.

Compositional semantics is the knowledge of how to compose the literal meaning of large syntactic units from the semantics of their subparts. Its utility is illustrated by the pair of sentences:

THE MAN HELD THE NUT (with a wrench).
THE WRENCH HELD THE NUT.

These two sentences are syntactically identical, but the subject of the first sentence is the agent of the action "hold," whereas the subject of the second is the instrument used by the agent. The lexical entry for the verb HOLD indicates that it is used to refer to actions in which an agent (usually a person) using an instrument exerts a force on some physical object. The syntactic subject of the verb might refer either to the agent or the instrument. But the semantics of HOLD indicate that these roles must be filled by objects of mutually disjoint classes of objects. Utilization of this knowledge allows a system to assign the role of agent to THE MAN, but assign the role of instrument to THE WRENCH.

Discourse knowledge concerns the way clues from the current context are used to help interpret a sentence. For example, if we have just been talking about this month's issue of BYTE, the noun phrase "the magazine" in:

I'VE ALREADY READ MY COPY OF THE MAGAZINE.

is easily understood *in this context* as referring to this month's issue of BYTE. Yet, we often have personal knowledge of hundreds of issues of various magazines.

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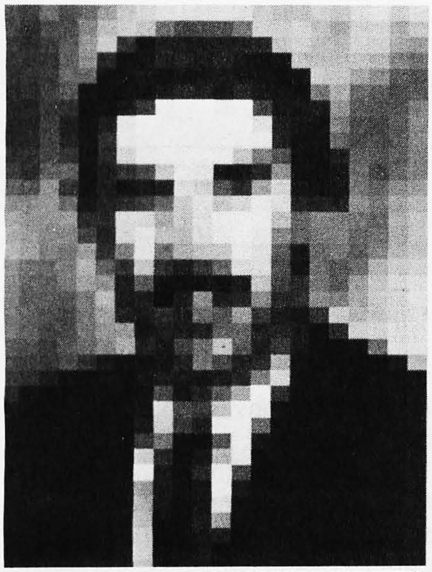

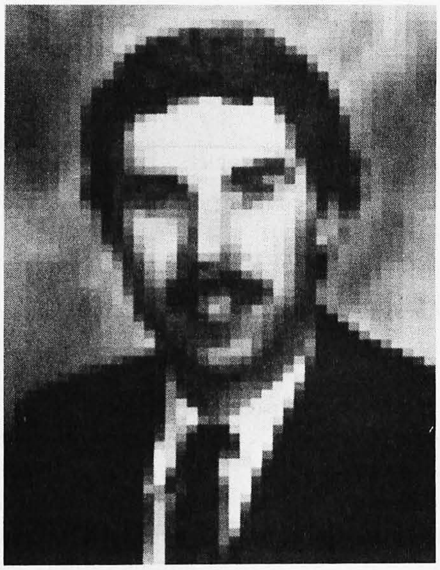

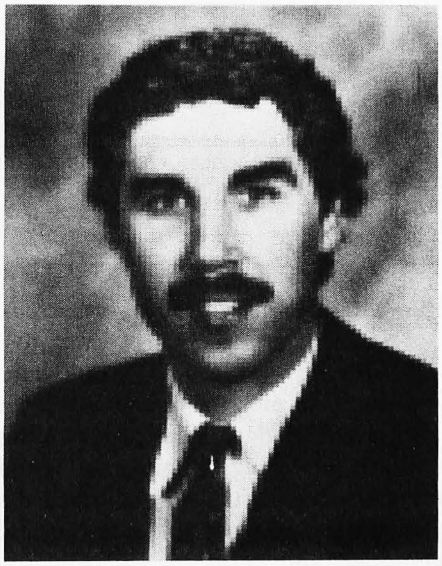

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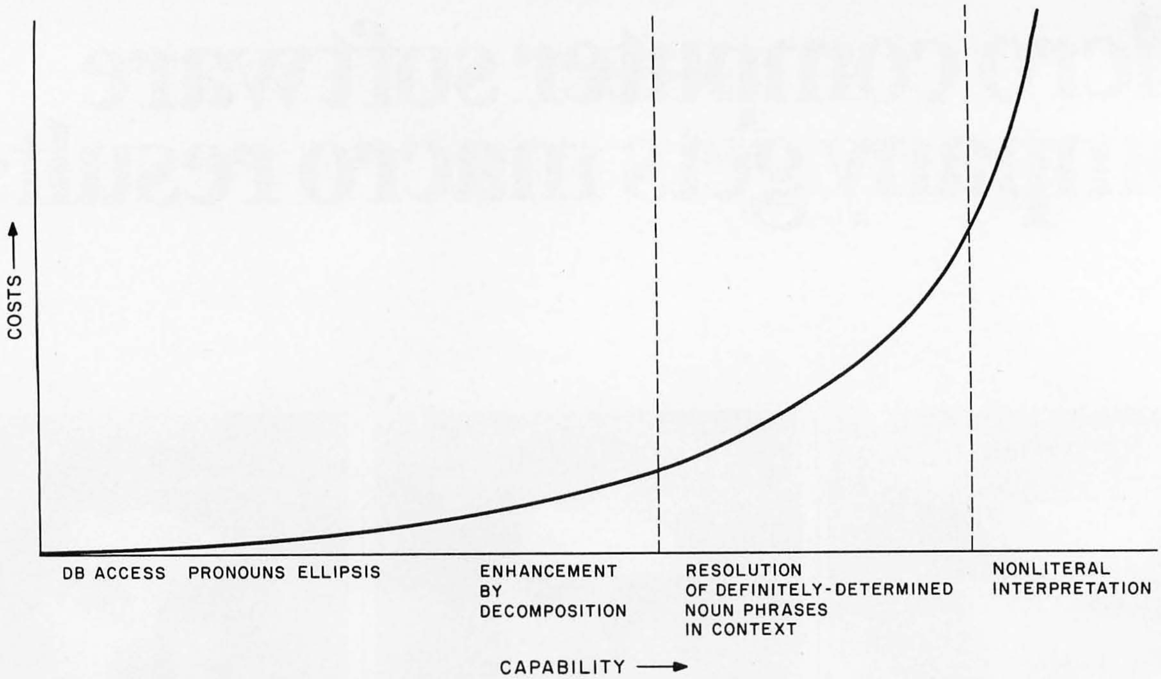

Figure 11: *A graph of capability versus cost for systems that can handle natural-language queries.*

The ability to pick the one of current interest is based on specific knowledge of the current situation.

World knowledge is concerned with information about how the world is currently configured and about physical constraints upon possible configurations. For example, we understand:

PRESIDENT REAGAN FLEW TO CALIFORNIA.

to mean that he *was flown* to California as a passenger in an airplane. Had the sentence been about a bird, we might have taken the sentence to mean that the bird did the flying.

As an example of how knowledge about the current physical situation can be of aid in understanding sentences, consider again the sentence:

PUT THE HAMMER IN THE TOOLBOX ON THE TABLE.

discussed in the earlier paragraph on syntax. If we know that the hammer is currently in a toolbox on the floor, the only interpretation of the sentence is to lift the hammer out of the toolbox and place it onto the table. The other interpretations are ruled out because they are impossible in the current state of the world.

Knowledge of mental states relates to comprehending the knowledge and goals of other participants in a dialogue. The use of such knowledge is shown in the locked-toolbox example in listing 7.

Cost as a Function of Capability

The preceding sections sketched a spectrum of natural-language processing capabilities—ranging from isolated questions about the data in conventional data bases, through the literal interpretation of utterances in dynamic contexts, to an understanding of the underlying goals and mental states of participants in a dialogue. As would be expected, progression through this spectrum entails rapidly escalating costs in two areas: the research and programming effort required to reach a particular level of capability, and the computing resources (measured in the number of machine instructions that must be executed and the memory requirements) needed to function at a given level.

This situation is illustrated graphically in figure 11, which plots cost as a function of system capability. Although the diagram shows a sharp rise in cost with increased capability, the situation is probably even more dramatic than indicated, and the cost scale might best be interpreted as being logarithmic.

The capability dimension has been separated into three major regions by two dividing lines. It appears that capabilities beyond (to the right of) the leftmost line require systems with explicit models of concrete objects in the world, the relationships among them, and the types of processes that can alter those relationships. The more advanced capabilities beyond the rightmost line require further enhancements for modeling such things as the mental states of dialogue participants.

Figure 12 repeats the curve of figure 11, but also shows curves for developing three kinds of systems. Systems on curve A are built without the use of explicit models. They cover most of the principal linguistic phenomena needed for accessing conventional data bases and, up to the point at which curve A intersects curve B, can be constructed and operated more economically than other types of systems. As the need for world models increases, at-

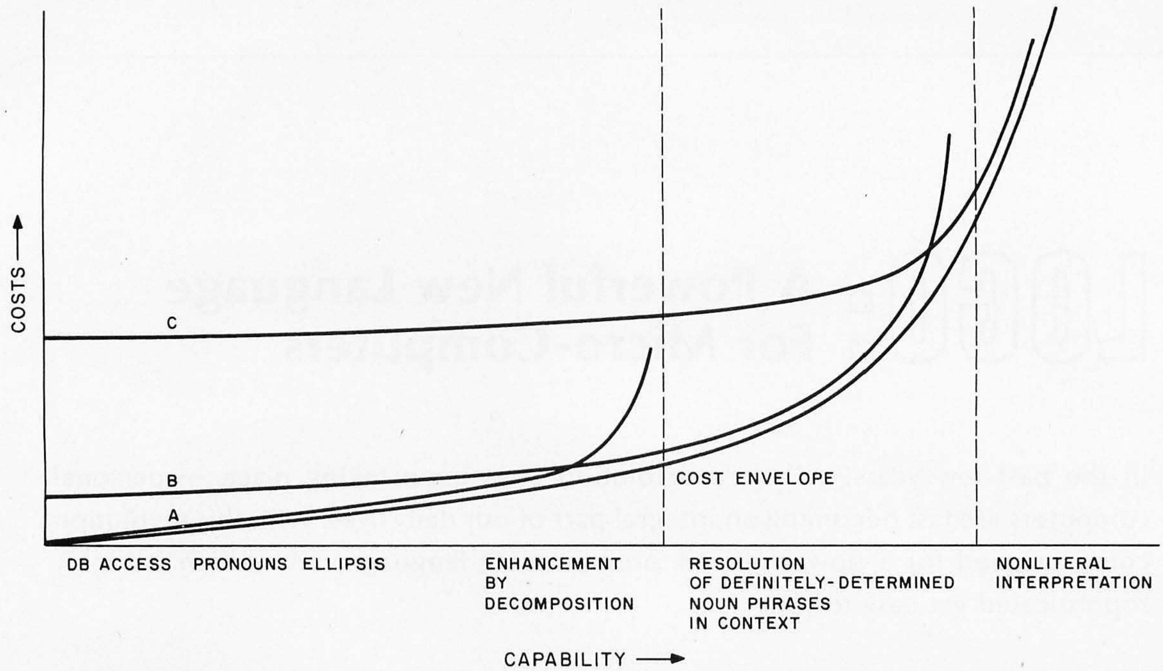

Figure 12: *A graph of capability versus cost for different kinds of natural-language systems. Curve A refers to systems that do not use explicit world models. Curve B refers to systems that do use explicit world models. Curve C refers to systems that are built on a knowledge base including information about the goals and beliefs of other intelligent entities.*

tempts to circumvent the problem by using various ad hoc methods become prohibitively expensive or downright impossible.

Systems on curve B are built with explicit world models that lack the ability to deal with intensional concepts, such as the goals and beliefs of others. Although these systems have greater capability potential than those on curve A, they entail considerable initial costs in the construction of machinery to support and exploit the models.

(*Intensional concepts* take into account the meaning, rather than just the truth values, of logical sentences. In standard logic, the truth value of a complex formula depends *only* on the truth of its subexpressions (eg: the truth of (P OR Q) depends only on the truth of P and the truth of Q; no other properties of P and Q matter). The operator BELIEVE, however, is intensional because the truth of "A believes that P" depends on the meaning of P, not just its truth value. The problem is that many of the rules of standard logic, such as substitution of equals for equals, do not apply when intensional operators are involved. To use a classic example, since "the morning star" and "the evening star" refer to the same object, it must be the case that "the morning star is Venus" is true if, and only if, "the evening star is Venus" is true. However, it might be that "John believes the morning star is Venus" is true, but that "John believes the evening star is Venus" is false because, although the two embedded sentences possess the same truth value, they differ in meaning.)

Systems on curve C, if any existed, would be built upon a knowledge base supporting many intensional concepts. The initial costs of creating computational machinery to support this level of sophistication appear to be quite high.

In today's computing environment, and in light of the current state of the art in natural-language processing, the only systems that perform robustly and efficiently are systems of type A. As mentioned in an earlier section on LADDER-like systems, there are a number of systems of this type, including one (INTELLECT, described in reference 10) available now as a commercial product.

A number of experimental systems of type B have been built, including SHRDLU, SAM, and TDUS. But these systems are currently of little practical value because they are relatively slow and use models that, while consuming considerable memory, cover pieces of the world too small to be of much more than academic interest.

Computational linguists and workers in related fields are devoting considerable attention to the problems of type-C systems. But currently, only bits and pieces of components for such systems are being constructed. For example, Moore (in reference 17) and Appelt (in reference 1) have devised formal methods for reasoning about the knowledge of others, and Perrault, Allen, and Cohen (in references 6 and 18) have devised systems that actually plan speech acts. But there is a huge gulf between the first experiments that demonstrate the feasibility of a principle and the creation of useful systems based on that principle. Our current state of understanding in natural-language processing is similar to that of the ancient makers of Chinese fireworks as compared with modern space research. In terms of achieving fluency in the field, our current experiments are merely fireworks poking a few holes in the darkness.

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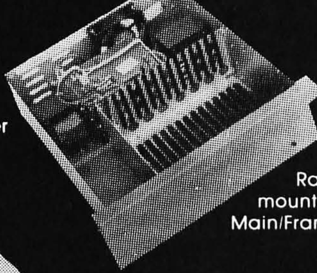

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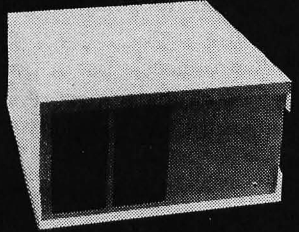

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language by machines may still be years away, it is important to realize that many practical applications of natural-language processing can be supported by systems of types A or B, both of which can be built *now*. Although the computational costs for natural-language processing will always be relatively high when compared with machine languages, the introduction of VLSI (very large-scale integration) technology promises to ease the attendant cost. Processes that were once performed only in the laboratory on research computers costing over one million dollars are becoming practical on personal computers. As a general trend, the expense of programming continues to rise while computer hardware continues to drop in price. For some applications, we may have already reached the point where it is cheaper to create systems that use subsets of English than it is to train people to use formal languages.

Current Capabilities of Type-A Systems

To reach a better understanding of the types of natural-language processing possible on a cost-effective basis using technology available today, consider the dialogue of listing 8, which shows some of the more advanced types of processing available in the LADDER system.

Interaction 1 shows how LADDER deals with sentences it cannot understand. After trying to interpret the input as first a complete and then an elliptic sentence, LADDER prints an error message indicating that the word "NY" is not known to it. The system also indicates that to complete the partial input, "How far is the Kennedy from the port of," it needs a construction matching its internal concept of a <PORT>. In interaction 2, the user seeks information about what LADDER would accept as a valid expression for a <PORT>. This is a very interesting question because it is not about the data in the data base, but rather a question about the language-processing system itself. LADDER can process questions about a variety of knowledge sources, including special routines that inspect its own internal information about the linguistic constructions it can accept. Using one of these special routines, LADDER produces a list of possible expressions for <PORT>, including the expression NEW YORK, which the user identifies as being what is meant by NY.

At this point, the user could rephrase the question by using NEW YORK in place of NY. But it is important for natural-language processing systems to accommodate the linguistic constructions their users are comfortable with—to accept inputs in the users' own terms, rather than force the users to master the system's terms. In particular, the learning of synonyms is relatively inexpensive computationally and quite helpful to users. In interaction 3, the user types a statement in English to tell LADDER that NY is a synonym for NEW YORK. Then, in interaction 4, the user asks that interaction 2 be tried again. This

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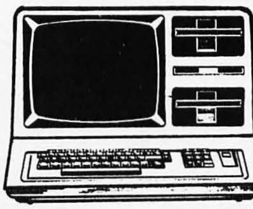

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Listing 8: *Another actual conversation with the LADDER system.*

1—**How far is the kennedy from the port of NY?**
Trying Ellipsis: ELLIPSIS HAS FAILED
The parser does not expect the word "NY" to follow "HOW FAR IS THE KENNEDY FROM THE PORT OF"
Options for next word of symbol are: <PORT>
2—**What is a <PORT>?**
PARSED!
"<PORT>" may be any sequence of words following one of the patterns:
<PORT> => CAPE TOWN
=> NEW YORK
=> NEW ORLEANS
[etc.]
3—**Define NY like New York.**
PARSED!
NY
4—**redo 2**
[i.e., How far is the Kennedy from the port of NY?]
PARSED!
(GCDIST 1974)
5—**Q1 Kennedy**
[System gives syntax error.]
6—**Let "Q1 kennedy" be a paraphrase of "what is the position, fuel status and homeport of the Kennedy"**
PARSED!
<S> => Q1 <SHIP>
7—**q1 kennedy**
PARSED!
(POSITION 4000N0600E PCFUEL 90 PORT MAYPORT)
8—**American subs in the North Atlantic**
Trying Ellipsis: Q1 AMERICAN SUBS IN THE NORTH ATLANTIC

SHIP	POSITION	PCFUEL	PORT
STURGEON	3700N7600W	100	NORFOLK
WHALE	3750N7700W	100	NORFOLK
ASPRO	3000N3000W	100	NORFOLK

[etc.]
9—**Let "show the forcestatus of the Kitty Hawk" be like "Display the employment and readiness condition of the Kitty Hawk. Print her destination. List ships in her organization."**
PARSED!
[New production added to system.]
10—**show the forcestatus of Kennedy**
PARSED!
[questions defined in 9 for Kitty Hawk are answered for the Kennedy.]
11—**Define "Kennedy no nagasa wa ikura desuka" like "what is the length of the kennedy."**
PARSED!
[Production added to system.]
12—**Fox no nagasa wa ikura desuka?**
PARSED!
LEN = 547

time, using the newly defined synonym, LADDER successfully interprets the question and produces the answer that the great-circle distance (labeled as GCDIST) from the *Kennedy* to New York is 1974 miles.

It is worth noting that LADDER must do more to answer queries 2 and 4 than merely retrieve information from a data base. Only the positions of ports and ships are stored in the data base—not the distances between them. Thus, LADDER interfaces not only with the data base, but also with programs that make calculations based on data-base information. Some of these are not trivial. For example, to find how long it would take a ship

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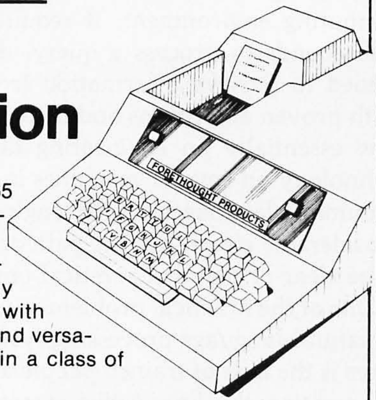

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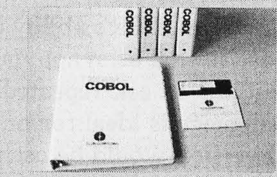

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to reach a given location, LADDER cannot simply divide the great-circle distance by the cruising speed of the ship, because the shortest path between two points on earth often crosses land masses. So LADDER computes routes that avoid land masses, which requires a knowledge of world geography.

Interactions 4 through 8 illustrate LADDER's ability to learn new syntactic constructions, as well as synonyms. Suppose a user has certain questions to ask repeatedly about different ships. Natural language is ideal for one-time questions, but a shorthand version would be useful for those used repeatedly. If, as in interaction 5, the user asks a shorthand question such as "Q1 Kennedy?", a syntax error will occur. However, the user can easily tell LADDER, by giving an example in English, how a new shorthand is to be interpreted. This is done in interaction 6. In response to this request, LADDER creates a new production rule that matches inputs that start with "Q1" and end with any expression designating a <SHIP>.

In interaction 7, this newly defined construction is used to ask for information about the *Kennedy*. In interaction 8, to obtain the same information for all the American subs in the North Atlantic, just "American subs in the North Atlantic" need be typed. LADDER's elliptical-processing routine, operating on the newly defined construction just as on the standard ones, fills in the rest. Because there are multiple answers to the question, a table is produced to display the data retrieved.

In interaction 9, the user tells LADDER to make a certain input sequence equivalent to not just one but a whole series of questions. It is as if the user were writing small programs in English, using English pronouns for formal parameters. In interaction 10, the new construction is used, but with a different ship than the one used to define the construction.

As an extreme example of this ability to accommodate the user-defined constructions, in interaction 11, the user tells LADDER a Japanese paraphrase of the English question, "What is the length of the Kennedy?" In interaction 12, the user poses this question about the *Fox*, rather than the *Kennedy*, entirely in Japanese.

The language-processing capabilities demonstrated in listings 3 and 8, while far from those possessed by a fluent user of natural language, seem quite adequate for a wide range of practical applications. This technology, using the language INTERLISP, is available today in a large computing environment. It requires approximately 500 milliseconds to process a query—far less than the time needed to retrieve information from a large data base. With proven algorithms and data structures in hand, it is now essentially an engineering task to implement this technology on smaller machines in widely available programming languages. Such engineering will require a considerable effort, but the path of development appears to be clear of major theoretical obstacles.

One of the practical problems currently limiting the use of natural-language processing systems for accessing data bases is the lack of trained people and good support tools for creating the knowledge structures needed for each new data base. In laboratory systems, researchers have manually compiled bodies of knowledge such as information about the vocabulary employed in a particular application or about the logical structure of particular data bases. Work has already begun on new methodologies to automate this task or even make it entirely unnecessary (see references 9, 15, and 25).

Conclusion

Considerably more research in computational linguistics will be required before mechanical devices can be created that are fluent in the use of natural language. However, current research efforts are shedding new light on the types of knowledge required for communication in human languages, as well as on prospective mechanisms for encoding and applying that knowledge in computers. These efforts are showing that language use is not an isolated intellectual activity; it also involves our basic facilities for commonsense reasoning and planning. A computer system fluent in a natural language will be a genuinely intelligent machine.

Although the fluent use of natural language by machines remains a long-term goal, a number of practical mechanisms have been developed to deal with significant fragments of language in specialized application areas. For many applications, an ability to communicate within such fragments is both sufficient for the task at hand and

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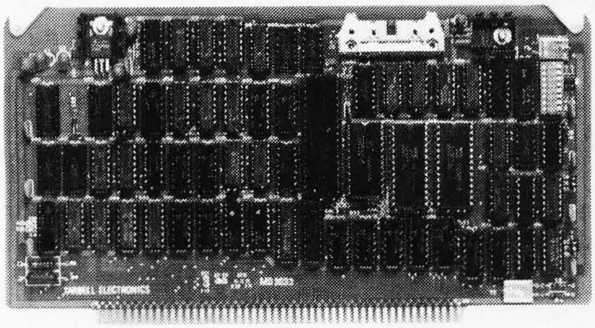

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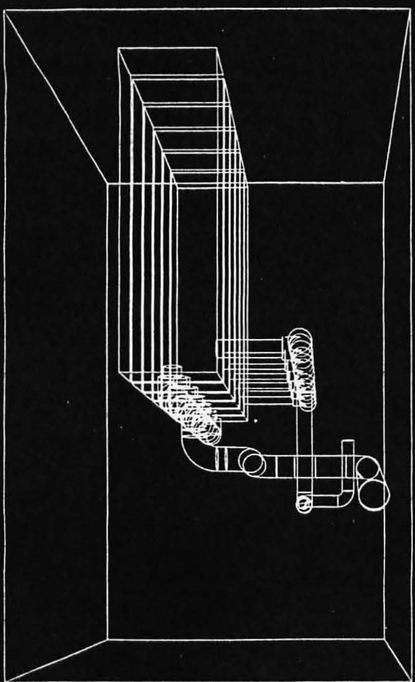

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clearly preferable to forcing users to learn machine-oriented languages. In coming years, we expect to see natural-language processing employed in an increasing number of practical applications, enabling more and more people to interact directly and effectively with computer systems. ■

Acknowledgments

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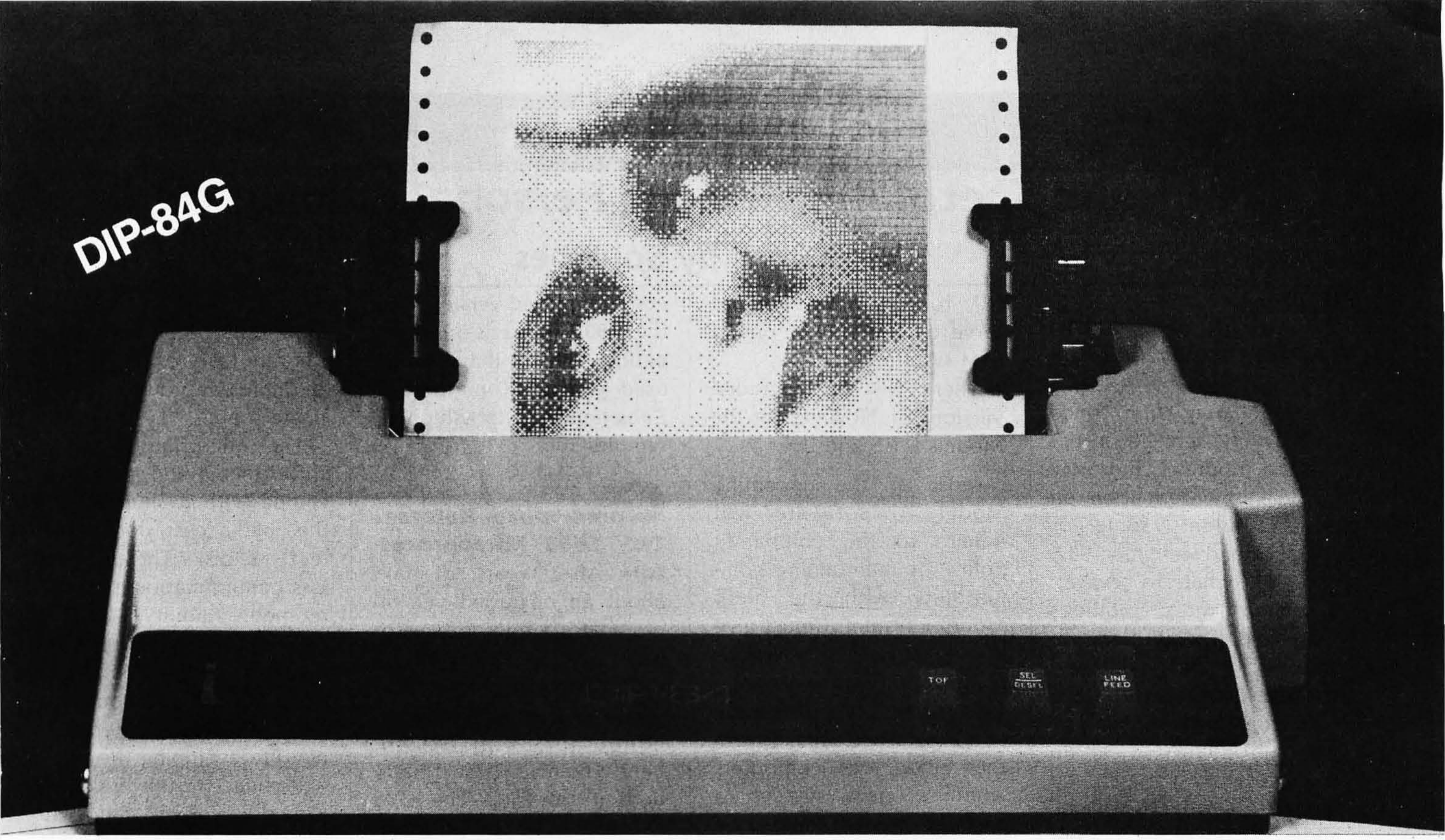

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- Radio Shack will introduce packages geared toward specific "vertical" markets (eg: medical, legal, educational, etc).
- There will be a software package that allows the Model II to read and write IBM-format disks and to serve as a terminal on an IBM system.
- There will be upgraded versions of TRSDOS for the Models I, III, and II.

Most of the upcoming Model III software will adhere to the company's policy of maintaining compatibility with the older Model I system. I must give Radio Shack credit for not making the mistake made by most other computer companies who virtually disown their older model computers when a new system is brought out, forcing customers to "junk" the older system and buy a new system merely to run new software.

Tandy also plans to change the name of its Radio Shack Computer Centers to Office Product Centers. These centers will sell copiers, facsimile machines, and other office products, as well as computer systems.

Zilog's New Fall Fashion: This fall Zilog will introduce an enhanced Z80 called the Z800. The designation doesn't mean that the Z800 is ten times better than the Z80 and only one-tenth as powerful as the Z8000, but Zilog claims it will have three times the performance of the Z80.

Zilog says that the Z800 will be fully compatible with the Z80 instruction set, which is a wise decision because the old software can still be used. It will contain circuits that facilitate multiplication, division, and memory mapping to access up to 4 megabytes of memory. It will be offered in a nonmultiplexed version, like the Z80, and a Z-bus-compatible version that can be used as a Z8000 peripheral. Zilog hopes to start shipping samples soon.

Commodore Releases The 6508 Microprocessor: After years of talk about an upgraded version of the 6502 microprocessor (used in the Apple II, Commodore PET, Atari 400 and 800, etc), Commodore Semiconductor, Norristown, Pennsylvania, has finally done it: the 6508. The 6508 has 256 bytes of programmable memory and an 8-bit parallel port. Its instruction set is compatible with the 6502's and its clock rate remains at 2 MHz. Commodore has let it be known that several other versions of the 6502 are forthcoming. They will include timer/counters, serial ports, and other functions. Its clock rate could go as high as 6 MHz.

Is There A Microfloppy Disk In Your Future? Sony is currently providing OEMs (original equipment manufacturers) with samples of its new 3½-inch "microfloppy"-disk drives. The drive represents a new technology that departs from the traditional 5- and 8-inch drives. Sony packs 437.5 K bytes per side into a drive that's 27% smaller than standard 5-inch models. Five-inch drives typically store about 250 K bytes (double-density) or 125 K bytes (single-density).

Even though the 3½-inch drive's compactness is very attractive for portable computers and word-processing systems, Sony is meeting some resistance from OEMs who are leary of purchasing an unproven product from a single source.

The microfloppy has a stiffer media and a rigid envelope with a shutter over the head-access slot to protect the disk. The result is less contamination and better media stability, which, in turn, allows greater accuracy and higher data density. Sony has also borrowed from its video-head technology in developing the read/write head for this drive.

Sample drives range in price from $400 to $500, not including a controller interface, although many of the currently available controllers can be used with little or no modifications. The price should drop to $200 to $300, in 500-unit quantities.

Sony plans to use the drives in its new word-processing systems, which will be introduced later this year. A 1-megabyte version of the device is expected early next year, and Sony will probably use it in its Series 35 small-business systems. There are rumors that Sony is developing a 3½-inch hard-disk drive.

Shugart and several other floppy-disk suppliers are taking a hard look at "microfloppies." There is no doubt that the trend is to smaller disk-storage units. The question really is whether or not manufacturers will adopt the Sony format or create a new standard ... or will something different emerge?

The IAPX432 Picture Becomes Less Fuzzy: Recently, *EDN* magazine commented on where the industry can be expected to go

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with the new Intel 32-bit microprocessor. I have taken the liberty of extracting some of the major comments here.

The iAPX432 was designed by and for computer scientists, rather than electrical engineers (as were Intel's 4-, 8-, and 16-bit microprocessors). The iAPX432's internal elements are less accessible than those in other microprocessors, so writing programs will be different.

"Instead of considering the machine in terms of bits and registers, you must focus on software objects . . . the 432 has no assembly language, per se; you might consider its instruction set to be a high-level language . . . a nearly optimum intermediate language specifically designed to simplify the task of writing efficient compilers. In turn, these compilers can effectively handle progams coded in high-level languages." The iAPX432's instruction set "does not constitute a complete operating system; rather, it contains the essential primitives from which you can construct such an operating system . . . the machine can't be programmed directly in code written in, say, Ada or FORTRAN; you need the appropriate compiler. Because the 432 simplifies system programming, programmers need not be hardware experts; thus personnel with a lower level of expertise can program it. Further, programs written in high-level languages can generally be developed more rapidly than those coded in assembly language.

"The machine performs arithmetic operations quickly and with a high level of precision. It also automatically prevents many typical programming errors (you can't inadvertently execute data, for example). Further, it provides functional redundancy checking, a feature that allows graceful system degradation when a CPU [processor] fails in a multiprocessing environment. And finally, the 432 ensures that all programs are naturally reentrant and recursive. The 432 chip set is complex and currently very expensive. It could incur speed penalties when performing certain operations."

The iAPX432 will not be the ultimate processor. "Although its instruction set is close to the ideal," says *EDN*, "it might be improved in other ways." It will not make 4-, 8-, and 16-bit microprocessors obsolete; and, in fact, it should increase the market for these as 'peripheral processors.'

"In summary, a good analogy is that the 432 is to standard microprocessors what the 7400 Series TTL was to discrete-device logic gates and flip-flops. It should free EEs [engineers] from many mundane system-design chores, allowing them to concentrate on more rewarding creative pursuits, while also reducing their projects' software costs. It's a minicomputer replacement, one that will open up scores of application opportunities."

Intel is already shipping a board-level iAPX432 evaluation system, called the Intellec 432/100. It consists of a board with a complete iAPX432 processor, RS-232C serial interface, evaluation software, and seven volumes of documentation. The user can plug the board into an Intel Intellec development system and create and execute iAPX432 programs using an object-oriented language. The 432/100 costs $4250.

The Intellec uses the Intel Multibus (IEEE-796), which has a 16-bit-wide data bus. The 32-bit-wide processor is interfaced to the bus via an interface-processor that handles data-bus transfers as two 16-bit words (the IBM 360, which was also a 32-bit processor, handled data transfers as 8-bit words, on its smaller machines).

Several S-100 (IEEE-696) bus-system manufacturers have iAPX432 development projects underway. I expect to see an S-100-based iAPX432 machine with disk operating system later this year.

The Software Shop: When I was a kid, I would go to the record shop and buy a copy of one of the top-ten records on the hit-parade. Well, soon I may be going to the "software shop" to buy a copy of one of the top-ten programs. At least that is what Cut & Curl hopes. It plans to open a franchised chain of stores that sell only software—"software supermarkets." Cut & Curl already franchises 500 Edie Adams Cut & Curl and Great Expectations Precision Haircutting salons. The first Programs Unlimited store has been opened, and Cut & Curl is talking about 100 more stores.

Random News Bits: Apple Computer Inc reported that sales for the first quarter of 1981 tripled over the same period a year ago. Sales were nearly $79 million, with a net of $9.2 million—a 16% increase over the previous quarter. Also, Apple claims to have produced over 200,000 Apple IIs and that the Apple III's "production problems" have been ironed out (most of the original design group has been fired). The Apple III is now in full production. . . . Zilog reported an $11 million loss on $42 million business for 1980. Zilog has yet to show a profit. . . . Commodore expects to introduce its "*Micromainframe*," with 132 K bytes of memory and 6502 and 6809 processors. It is really a PET computer with a second processor (the 6809). You can elect to run either the 6502 or the 6809. Commodore claims to have BASIC, FORTRAN, APL, Pascal, and an Assembler ready for the machine. COBOL will come later. The software was developed at the University of Waterloo in Ontario, Canada. Commodore has not yet set the price. . . . Interlude, Houston, Texas, claims to have sold 15,000 copies of its sex-oriented software package for the Apple II and TRS-80 computers. The program asks users questions about themselves and their partners, and then tells them how to enjoy their spare time. . . . Florida Data Corporation, Melbourne, Florida, has introduced two serial dot-matrix printers that can rocket along at 600 cps (characters per second) for draft or data-processing output and at 150 cps for letter-quality output—that's three times faster than any daisy-wheel printer. The letter-quality output is produced by passing the head over each line four times, with the dots displaced slightly on each pass to fill in the character. . . . Intel will introduce a set of two integrated circuits for the Ethernet controller and interface that will allow a user to implement the physical and data links. A little bit of extra circuitry, some special cables, and interfacing software, and you can connect any personal computer to an Ethernet system. . . .

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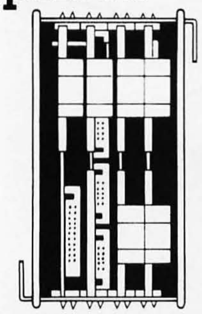

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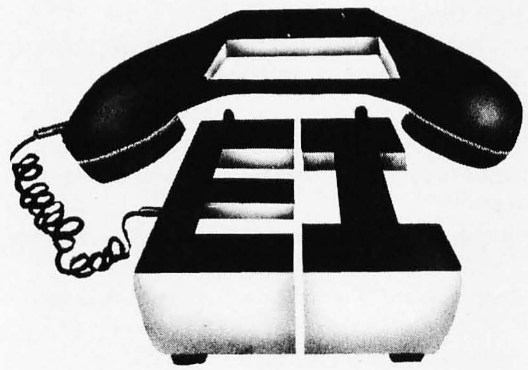

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BYTELINES

ments (TI) will phase out its magnetic bubble-memory products as part of a company-wide retrenchment program. The move, ironically, comes less than a month after TI announced it was expanding its line. Rockwell International announced a similar move earlier this year. Besides dropping its bubble-memory line, TI also announced plans to get out of the digital-watch business and lay off 3% of its work force.

The 64 K-Bit Memory Devices Are On The Way: Intel and a few other integrated-circuit makers are now shipping 64 K-bit memories. Prices are currently in the $30 range but are expected to drop to around $8 by year's end. Look for products using these circuits by early next year. It's rumored that Apple has placed an order for 60,000 of the devices, at $12 a chip, for a new business computer.

Reportedly, Intel has 256 K-bit memory devices in the prototype stage. Using the 64 K-bit devices, you could build a 64 K-byte memory system using only eight memory circuits. When the 256 K-bit products become available, only two circuits will be required.

MAIL: I receive a large number of letters each month as a result of this column. If you write to me and wish a response, please include a self-addressed, stamped envelope.

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Ask BYTE

Conducted by Steve Ciarcia

Ciarcia's Circuit Court?

Dear Steve,

I am a member of the Evanston Township High School Computer Club, and I was wondering if you could settle a dispute for me. The supervisor of our computer room will not allow us to double-side our floppy disks because of the fact that they accelerate the accumulation of oxide and dust deposits on the read/write head of the disk drive. Is this true?

Scott Coleman
Evanston Il

I don't like to jump into the middle of disputes, but if you can live with my opinion, I will voice it. It should not make any difference whether you have a single-sided or double-sided disk. The disk-drive head does not come in contact with the oxide surface: it rides above it. So, theoretically, it should not cause any accumulation on the read/write head.

Now, that's in theory. In truth, there's always some oxide that comes off on the head, but if the computer room is doing regular maintenance, which is to clean the heads every once in a while, it should never be built up to a point at which it makes any difference anyway.

Perhaps the way to settle this is to have the computer club volunteer to clean the disk drives once in a while. . . . **Steve**

Tools of the Course

Dear Steve,

I am beginning implementation of a hands-on microcomputer experimentation and interfacing course here at the University of Dubuque Theological Seminary. I want to establish a digital-microprocessor laboratory. What would you consider to be the *minimum* test equipment necessary? Our financial resources are somewhat limited, so your advice would be most helpful.

Terry A Ward
Dubuque IA

At the very minimum, I would recommend that you get an oscilloscope. If you can afford it, it should be dual-trace and have at least a 15 MHz bandwidth. With it, you can troubleshoot many pieces of equipment and perform some logic-analyzer functions. If you can afford it, of course, a logic analyzer is always a good piece of equipment to have around. However, you can spend so much time teaching people how to use a logic analyzer that you don't have any time left in the course.

Other than an oscilloscope, the only other piece of equipment that you probably need would be a simple digital voltmeter (DVM) or digital multimeter.

Often the things that are needed when teaching students are not the things that you can buy off the shelf as test equipment. Frequently, simpler equipment, such as a buffered LED (light-emitting diode) that functions as a logic probe, is what's necessary.

A logic probe, 'scope, and a DVM should take care of practically anything that would arise. . . . **Steve**

Auto Warning

Dear Steve,

In a book on microcomputers that I read, the author predicted that an automotive warning device that would tell drivers they were too close to another vehicle would be devised.

It occurred to me that such a gadget might be realized right now using the Polaroid development kit and a simple single-board computer. Software, it seems to me, might be the biggest hurdle. What do you think?

Bob Crafts
Edgartown MA

The Polaroid ranging sensor is definitely usable for a driver-warning device like the kind you mentioned. However, I don't see this sensor being used as a crash-avoidance device because its response time is a little slow. I have seen one company using the device on each side of a car's fenders, with a dash-mounted display for the driver. In my mind, while this may work, its feasibility and production is another matter. It would seem to be rather expensive unless produced in large quantities.

When using the Polaroid development kit in an automobile, you must try to isolate the ignition noise from any power being drawn from the car's electrical system. From my experience, the Polaroid ranging kit is also electromagnetic interference and static sensitive. If used in a car, it should be in a shielded enclosure. . . . **Steve**

Scheming Schematics

Dear Steve,

I would like to expand an Atari 400 or 800 with minimum programmable memory to a full 64 K memory by using 4116 chips. To this expansion board, I would also like to add RS-232C circuitry to handle a printer and modem. Of course, it would need its own power supply.

I am a technician with a good background in digital electronics but not a circuit designer. Where can I find the necessary schematic and parts list?

Emanuel Soffer
Rockaway NY

Expanding the memory and adding RS-232C to the Atari are two completely different problems, each requiring diverse amounts of talent. The 6502 has no internal refresh logic, as does the Z80. External refresh logic must be added.

An RS-232C serial port can be added fairly easily to the expansion connector on the side of the Atari if the proper software is added to the unit. One company that has been working on this is the Code Works, POB 550, Goleta CA 93017. I suggest that you write the Code Works (attention Ron Jefferies) asking about its serial port for the Atari. It should be fairly inexpensive because it's practically all software.

Presently, it is cheaper to use static memory on the Atari. Whether this situation continues will be determined by the prices of dynamic versus static memory, the development of an inexpensive refresh method, or the evolution of new quasistatic programmable memories, such as the Zilog Z6132. If any readers have a good circuit for using dynamic memory with a 6502, I'd appreciate seeing it. . . . **Steve**

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Dear Steve,

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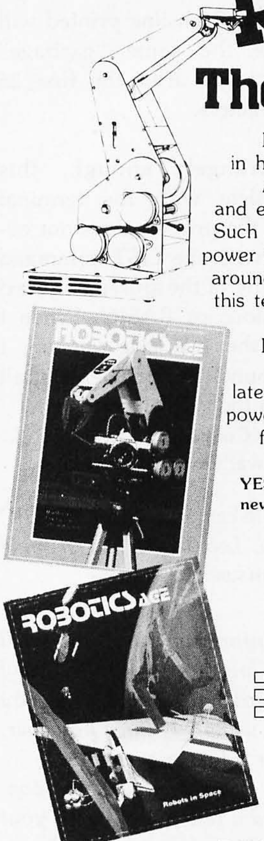

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This problem appears to be entirely within the computer itself. Local experts and Technical System Consultants (it wrote the software) all seem to be baffled by the problem.

The computer is a SwTPC (Southwest Technical Products Corporation) 6800 microcomputer wth 32 K bytes of programmable memory (two 4 K-byte boards at 0000 to 1FFF hexadecimal and three 8 K boards at 2000 to 7FFF), an A2 processor board with SwTBUG monitor, MP-C interface, and MF-68 dual disk drives. The system runs under Flex 1.0. The peripherals are: CT64 terminal, AC30 cassette interface, GE Terminet 300 hard-copy terminal, and a PR40 parallel printer.

Running MEMTEST1 indicates one small problem at address 3C2D hexadecimal, but, other than that, there appear to be no problems.

The problem appears when using the PRINT statement running under Disc BASIC 3.0 and all versions of 8 K BASIC. When running a program with any more than 25 characters in a PRINT statement *anywhere* in the program, one of the following happens:

- The CT64 terminal will go into numerous control character gyrations after printing the first 25 characters.
- Both printers print the same "garbage" after the 25 characters. Each line printed will have the same "garbage" characters after the first 25 characters.

Strangely enough, this problem with the terminal and the printers does not occur with the LIST command on any of the aforementioned versions of BASIC. When I use the 4 K-byte version, I encounter no problems at all with the PRINT statement.

Dave Coultish
Ottawa, Ontario, Canada

I asked our local SwTPC guru, Leo Taylor, to provide an answer. . . . **Steve**

Unfortunately, I can't tell you anything solid, because I do not have the BASIC you are using. I can, however, offer a few suggestions.

I suspect you have confused a few people with your software description. To the best of my knowledge, I guess you have Miniflex and SwTPC BASIC 3.0. Many people are confused between versions of Flex. If you have 5-inch floppy-disk drives, you can't have Flex 1.0 because it requires 8-inch drives and memory at hexadecimal A000. TSC did not write BASIC 3.0; it was written by Rober Uterwick and adapted by SwTPC.

There is never a "small memory problem." BASIC has a way of finding memory problems that defy any other means of detection. Since you mentioned the memory error, you probably haven't swapped boards to eliminate it as a suspect. You have enough memory to remove any one board and still have the required 12 K starting at address 0000 and 4 K at hexadecimal 7000. The BASIC you are using will scan for end-of-memory. If it finds a byte it considers bad, it stops scanning, backs up one address, and loads its stack. If the end-of-memory is near the start of a page (such as 3C2D), BASIC will fail to reserve enough stack space. This can cause all sorts of problems. Thus, a minor memory problem becomes a major malfunction. . . . **Leo Taylor**

Control Search

Dear Steve,

My company has been looking for a way to communicate with a robot by using radio control. We were hoping that you might know of an integrated circuit that can be used. We need three or more digitally proportional channels that can be easily controlled by a computer.

Michael Dubno
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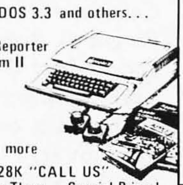

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Books Received

Apple Crunch, novel by Frederic Vincent Huber. New York: Seaview Books, 1981; 15 by 22 cm, 264 pages, hardcover, ISBN 0-87223-687-0, $10.95.

Calculator Clout: Programming Methods for Your Programmable, Maurice D Weir. Englewood Cliffs NJ: Prentice-Hall, 1981; 18.5 by 24.5 cm, 235 pages, hardcover, ISBN 0-13-110411-X, $17.95; softcover, ISBN 0-13-110403-9, $8.95.

Computers for Everybody, Jerry Willis and Merl Miller. Beaverton OR: Dilithium Press, 1981; 14 by 22 cm, 173 pages, softcover, ISBN 0-918398-49-5, $4.95.

Computer Literacy: Problem-Solving with Computers, C E Horn and J L Poirot. Austin TX: Sterling Swift Publications, 1981; 18.5 by 23.5 cm, 304 pages, softcover, ISBN 0-88408-133-8, $13.95.

Computer Solution of Large Sparse Positive Definite Systems, Alan George and Joseph W Liu. Englewood Cliffs NJ: Prentice-Hall, 1981; 16 by 23.5 cm, 324 pages, hardcover, ISBN 0-13-165274-5, $24.95.

The Devil's DP Dictionary, Stan Kelly-Bootle. New York: McGraw-Hill, 1981; 13.5 by 20.5 cm, 141 pages, softcover, ISBN 0-07-034022-6, $7.50.

Electronic Circuits Note Book, Proven Designs for Systems Applications, edited by Samuel Weber. New York: McGraw-Hill, 1981; 22 by 28 cm, 344 pages, hardcover, ISBN 0-07-019244-8, $32.50.

Manual of Pharmacologic Calculations with Computer Programs, Ronald J Tallarida and Rodney B Murray. New York: Springer-Verlag, 1981; 16 by 24.5 cm, 150 pages, hardcover, ISBN 0-387-90500-6, $17.50.

Microsoft FORTRAN, Paul M Chirlian. Beaverton OR: Dilithium Press, 1981; 14 by 22 cm, 333 pages, softcover, ISBN 0-918398-46-0, $14.95.

Outland, The Movie Novel, edited by Richard J Anobile, from the screenplay by Peter Hyams. New York: Warner Books, 1981; 22 by 27.5 cm, 160 pages, softcover, ISBN 0-446-97829-9, $9.95.

Program Flow Analysis: Theory and Applications, S S Muchnick and N D Jones. Englewood Cliffs NJ: Prentice-Hall, 1981; 16 by 23.5 cm, 418 pages, hardcover, ISBN 0-13-729681-9, $23.50.

Scientific Analysis for Programmable Calculators with Algebraic Operating Systems, H R Meck. Englewood Cliffs NJ: Prentice-Hall, 1981; 18.5 by 24.5 cm, 175 pages, hardcover, ISBN 0-13-796417-X, $15.95; softcover, ISBN 0-13-796409-9, $7.95.

Software Metrics, edited by A J Perlis, F G Sayward, and M Shaw. Cambridge MA: The MIT Press, 1981; 16 by 23.5 cm, 404 pages, hardcover, ISBN 0-262-16083-8, $25.

Thirty-Two BASIC Programs for the Exidy Sorcerer, T Rugg, P Feldman, and K McCabe. Beaverton OR: Dilithium Press, 1981; 14 by 22 cm, 265 pages, softcover, ISBN 0-918398-35-5, $16.95.■

This is a list of books received at BYTE Publications during this past month. Although the list is not meant to be exhaustive, its purpose is to acquaint BYTE readers with recently published titles in computer science and related fields. We regret that we cannot review or comment on all the books we receive; instead, this list is meant to be a monthly acknowledgment of these books and the publishers who sent them.

Clubs and Newsletters

Join a Georgian Club

The Statesboro TRS-80 Users Group is interested in all aspects of TRS-80 computers, especially word-processing and business applications. Contact the club c/o Dr Russell A Dewey, 223 N Edgewood Dr, Statesboro GA 30458, (912) 681-3631.

Apple Guild

The Apple Guild promotes the interchange of information and applications among Apple users. The Guild maintains a collection of hardcopy material and software at the Apple Resource Center. The Resource Center is located at Massasoit Community College, Brockton, Massachusetts. The Guild publishes a quarterly journal and supports a telecommunications system at (617) 767-1303. Contact the Apple Guild, POB 371, Weymouth MA 02188.

Ohio Apples

The NEO Apple Corps is devoted to Apple computers. The Corps publishes a newsletter called *Apple Bits*. Contact the group at 21750 Miller Ave, Euclid OH 44119, (216) 486-2317.

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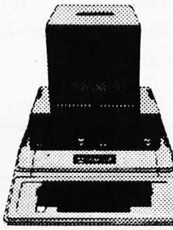

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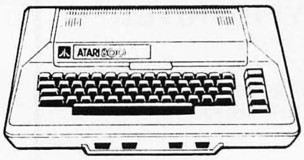

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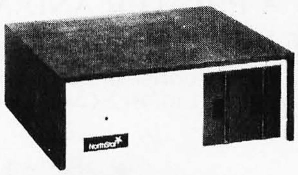

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members. Contact the Micropolis Users Group at 604 Springwood Cr, Huntsville AL 35803, (205) 883-2621.

MCMS

MCMS (Military/Civilian Microcomputer Society) is devoted to the exchange of ideas and information about all types of computers. No particular microcomputer is emphasized. Contact the Military/Civilian Microcomputer Society, Gunter AFS, AL 36114, or call Jim Wolfe at (205) 279-4816.

Lists of Used Microcomputers

The Used Computer Exchange is a listing service that puts you in direct contact with sellers. Customers pay $5 for quotes on completed transactions and for full current listings. Sellers pay a commission only if a transaction is completed with a buyer referred by the Exchange.

The Used Computer Exchange lists any microcomputer hardware that originally sold in the $400 to $25,000 price range. Contact the Used Computer Exchange at 2329 Hunters Woods Plz, Reston VA 22091, (800) 327-9191, ext 61; in Virginia, (703) 471-0044.

1802 Fans

The VIP Hobby Computer Association is made up of users of the RCA VIP and other 1802-based microcomputers. The group's newsletter, *Viper*, contains programs, advice, and helpful hints. Membership fees are $12 per year, which includes the newsletter. Contact the VIP Hobby Computer Asso-

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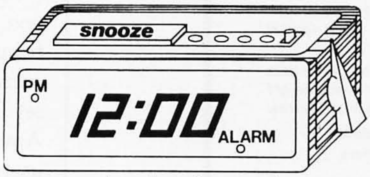

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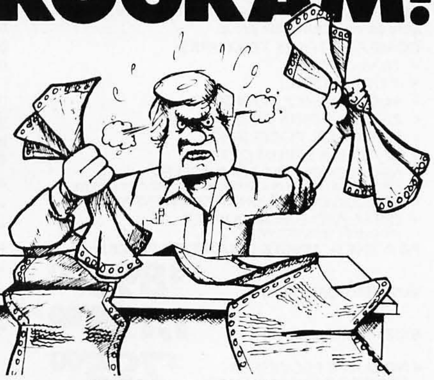

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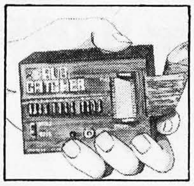

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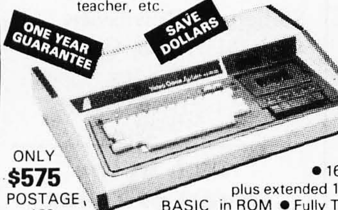

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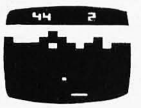

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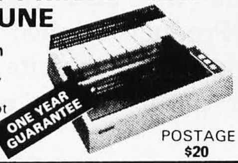

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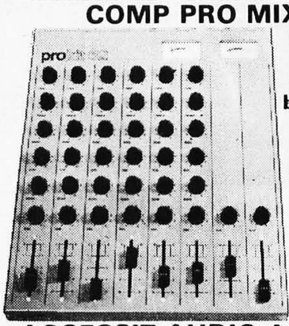

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ciation, 32 Ainsworth Ave, East Brunswick NJ 08816.

Amethyst Users Group In Texas

Amethyst is an expandable text editor and formatter distributed by Mark of the Unicorn. Amethyst's command set is written in BDS C. The Amethyst Users Group assists users in developing extensions to Amethyst. Annual membership is $6, and floppy disks are $6. Contact the group at 1633 Royal Crest, #1128, Austin TX 78741, (512) 441-9466.

Sorcerer Users Newsletter

Port Fe is a newsletter for Exidy Sorcerer users. It includes articles, equipment reviews, and program listings. Subscriptions are $15 in Canada and $23 elsewhere. Contact the Sorcerer Users Group Toronto, POB 1173, Station B, Downsview, Ontario, M3H 5V6, Canada.

Club In the Heart of Texas

The Midland Microcomputer Users Association meets at 7 PM on the first Wednesday of the month at the Sound Machine in Midland, Texas. The club's main interests are exchanging information and assisting new computer hobbyists. If you own a microcomputer, you are invited to join, even if you don't live in the area. The annual fee is $15, and a newsletter is being worked on. Contact the Midland Microcomputer Users Association, 1024 Andrews Hwy, Midland TX 79701; or contact Mark T Cruse, 3609 Stanolind, Midland TX 79703, (915) 694-4868.■

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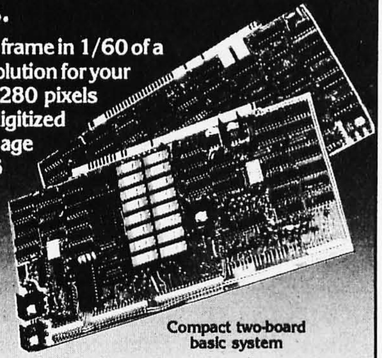

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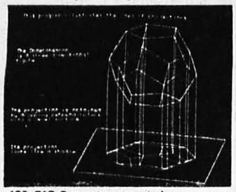

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Event Queue

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September-December
Four Seminars from Management Information Corporation (MIC), various sites throughout the US. These seminars are designed for businesspeople who need an introduction to system selection and use. For a complete schedule of seminars, fees, and locations, contact Carol Bell, c/o MIC, 140 Barclay Ctr, Cherry Hill NJ 08034, (609) 428-1020.

September 8-10
An Introduction to Microcomputers for the Electronic Data-Processing Professional, Las Vegas NV. This course is designed for electronic data-processing managers, systems analysts, and engineers. Some of the course topics are applications for microcomputers in a large company, programming in BASIC, and future developments of the microcomputer. A general knowledge of computers is recommended. For dates and other information, contact Byte Educational Services, 2412 Second Ave, Seattle WA 98121, (206) 625-1961.

September 9-11
Eurographics '81, Technical University, Darmstadt, West Germany. Almost seventy exhibitors are expected to attend this computer-graphics show. Detailed information can be obtained from Diebold Deutschland GmbH, Attn: Dr H J Grobe, Feuerbachstrasse 8, D-6000 Frankfurt/Main, West Germany.

September 9-12
Workshops on Pascal and Programming Techniques, University of California Extension, Santa Clara CA. An introduction to Pascal and modern programming techniques and style will be provided in this sequence of four one-day workshops. The sequence is structured so that each workshop is independent but leads to the next. Fees are $175 for individual courses and $600 for the four-part sequence. Contact Continuing Education in Engineering, University of California Extension, 2223 Fulton St, Berkeley CA 94720, (415) 642-4151.

September 10-11
Office Automation Systems, Holiday Inn, Chicago City Centre, Chicago IL. This seminar will feature discussions on office automation. Among the topics to be covered are Ethernet, Xerox strategies, and worker acceptance of office automation. For information, contact Architecture Technology Corporation, POB 24344, Minneapolis MN 55424, (612) 925-2930.

September 10-13
The Second Annual Mid-West Computer Show, McCormick Place, Chicago IL. This show features office systems, data- and word-processing equipment, telecommunications equipment, microcomputers, computer graphics, peripherals, and other related supplies. For information, contact the National Computer Shows, 824 Boylston St, Chestnut Hill MA 02167, (617) 739-2000.

September 14-17
Software Info '81, Merchandise Mart Expocenter, Chicago IL. The conference theme is "Productivity Through Packaged Software." Fran Tarkenton is the keynote speaker. The president of Input, Peter Cunningham, will deliver an address. For more information, contact Software Info, 1730 N Lynn St, Suite 400, Arlington VA 22209, (703) 521-6209.

September 14-17
COMPCON Fall '81, Capital Hilton Hotel, Washington DC. The conference theme is "Productivity—An Urgent Priority." This conference is intended to provide a focus on productivity throughout the computer industry. General inquiries for program information should be addressed to COMPCON Fall '81, POB 639, Silver Spring MD 20901, (301) 589-3386.

September 15-16
Workstations, The Convergence of Information Processing and Telecommunications, New York NY. The role of workstations for professional, managerial, and executive use is the focus of this two-day seminar. Speakers will discuss the Xerox Star workstation and other new designs. For more information, contact Probe Research Inc, POB 251, Millburn NJ 07041, (201) 376-7730 or (212) 732-5417.

September 15-17
Wescon/81, Brooks Hall, Municipal Auditorium, and Hilton Hotel, San Francisco CA. Sessions on communications, components and devices, computer and microprocessor hardware and software, office automation, and memory systems will be presented. Exhibits of computer equipment and related products will be featured. Contact Electronic Conventions Inc, Suite 410, 999 N Sepulveda Blvd, El Segundo CA 90245, (213) 772-2965.

September 16-18
Diagnostic Software: Planning and Design, Colonial Hilton Inn, Wakefield MA. The Polytechnic Institute of New York is cosponsoring this seminar for design, test, and diagnostic engineers and managers. Design examples, lectures, informal sessions, and individual and group diagnostic-programming sessions are part of the course. Tuition is $495. Contact Professor Donald D French, Institute for Advanced Professional Studies, One Gateway Ctr, Newton MA 02158, (617) 964-1412.

September 16-18
The Engineer As a Communicator, Crystal City Marriott, Arlington VA. This conference is sponsored by the IEEE (Institute of Electrical and Electronics Engineers) Professional Communication Society. Some of the topics to be covered are communications technology, computers in technical communications, and information gathering, storage, and retrieval. Contact Dr Daniel Rosich, School of Business Administration, University of Connecticut, Stamford CT 06903, (203) 322-1673.

September 21-24
Microtest '81, University of Kent, Canterbury, England. This symposium will cover the testing, maintenance, and reliability of microelectronic systems from development to field use. Development systems, emulators, reliable software and hardware, and high-level languages are some of the issues to be discussed. Contact the Symposium Secretary, Microtest '81, SERT, 57-61 Newington Causeway, London, SE1 6BL, England.

September 24-25
Microprocessors: Hardware, Software, and Applications, Worcester Polytechnic Institute, Worcester MA. Among the courses to be offered are hardware and software basics, selection and evaluation of microprocessors, memory and input/output systems, multiprocessor systems, real-time-system design, and debugging and circuit testing. For more information, contact Ginny Bazarian, c/o Continuing Education, Worcester Polytechnic Institute, Worcester MA 01609, (617) 753-1411, ext 517.

September 24-27
The Second Annual Mid-Atlantic Computer Show, Washington Armory, Washington DC. For details, see September 10-13.

September 30-October 2
Data and Telecommunications Expo '81, Rhein-Main-Halle, Wiesbaden, West Germany. This exhibition and conference will cover data communications, distributed data processing, and telecommunications networks. Future telecommunications developments, international network management, and graphics will also be discussed. Contact Cahners Exposition Group, 222 W Adams St, Chicago IL 60606, (312) 263-4866. In Europe, contact Kiver Communications S A, U K Branch Office, Millbank House, 171/185 Ewell Rd, Surbiton, Surrey, KT6 6AX, England.

October 1981

October-November
Workshops from Virginia Polytech, Virginia Polytechnic Institute and State University, Blacksburg VA. Workshops on microcomputer-design interfacing and programming, digital electronics

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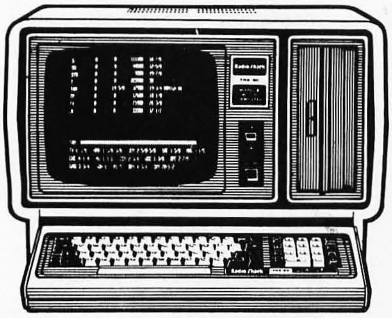

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for automation and instrumentation, and sessions using the TRS-80 are part of the curriculum. All workshops are hands-on with participants designing and testing concepts on the actual hardware. Contact Dr Lindy Leffel, Virginia Polytechnic Institute and State University, Blacksburg VA 24061, (703) 961-5241.

October 7-9

Institute on Microcomputers for Instruction and Research in Higher Education, Jane S McKimmon Center, North Carolina State University, Raleigh NC. The institute is designed to help high-level educators learn about the microcomputer and the role it can play in higher education. Contact Joyce Currie, c/o North Carolina Educational Computing Service, POB 12035, Research Triangle Park NC 27709, (919) 549-0671.

October 7-21

The 1981 Far East Computer Tour, Japan, South Korea, Taiwan, and Hong Kong. This tour group will visit various computer-related conferences and exhibitions throughout the Far East. Transportation for this three-week tour, plus shows, meals, and other items are included in trip packages, ranging in price from $2290 to $3095. For more information, contact Terry Butler, Commerce Tours International Inc, 870 Market St, Suite 742-744, San Francisco CA 94102, (415) 433-3072.

October 9-11

Rhode Island Computer and Video Electronics Show, Providence Civic Center, Providence RI. This is the first major computer exhibition and show to be held in Rhode Island. Exhibitors and sales teams will present the latest

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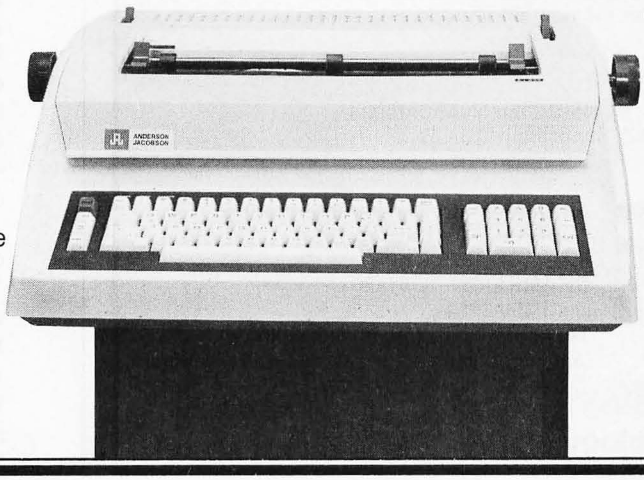

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in computers and video products for business, industry, government, education, and home use. Contact New Leaf Productions, Suite 335, 77 Ives St, Providence RI 02906, (617) 679-0089.

October 12-15

Information Management Exposition and Conference: INFO 81, Coliseum, New York NY. Discussions on prepackaged, customized prepackaged, and custom-designed software will complement hardware and software exhibits. For more information, contact Clapp & Poliak Inc, 245 Park Ave, New York NY 10167, (212) 661-8410.

October 13-15

Understanding and Using Computer Graphics, New York NY. Headed by Carl Machover, this two-day seminar examines the state of the art in graphic systems. The focus will be on hardware, software, and applications. Contact Bob Sanzo, c/o Frost & Sullivan Inc, 106 Fulton St, New York NY 10038, (212) 233-1080.

October 15-18

The Third Annual Northeast Computer Show and Office Equipment Exposition, Hynes Auditorium, Boston MA. This show will feature hardware, software, and supplies for business, education, government, home, and office use. Office systems and equipment will also be shown. Contact National Computer Shows, 824 Boylston St, Chestnut Hill MA 02167, (617) 739-2000.

October 16-23

The Fourteenth Brazilian Computer Conference and Exhibit, Anhembi Convention and Exhibit Halls, São Paulo, Brazil. This conference will feature technical talks, conference tutorials,

roundtable discussions, and special events. Computer-aided design and manufacture in developing countries will also be discussed. Contact Sucesu São Paulo, Rua Tabapuã, 627-1.° andar, 04533, Saõ Paulo, S P, Brazil.

October 18-20
The Annual Conference of the New York State Association for Educational Data Systems (NYSAEDS), Syracuse NY. NYAEDS is made up of people with an interest in computers and education. Workshops on the educational uses of microcomputer software will be held. Contact Don Ross, Ardsley High School, Ardsley NY 10502.

October 19-23
Systems '81, Munich, West Germany. Computer systems and their applications will be featured. Additional information is available from Kallman Associates, 30 Journal Sq, Jersey City NJ 07306, (201) 653-3304.

October 20-22
The Annual Government-Industry Data Exchange Program (GIDEP) Workshop, Rickey's Hyatt House, Palo Alto CA. The GIDEP annual workshop is open to anyone interested in the exchange of technical information relating to engineering, failure experience, reliability, and maintainability. Contact the Officer-in-Charge, GIDEP Operations Center, Corona CA 91720.

October 20-22
Computerized Office Equipment Expo, Southwest, Astrohall, Houston TX. Approximately 100 exhibitors will present office equipment and supplies, including word-processing systems, at this show. Contact Cahners Exposition Group, 222 W Adams St, Chicago IL 60606, (312) 263-4866.

Event Queue

October 21-24
COMPUTA 81, World Trade Center, Singapore. This international show attracts professionals and buyers from Hong Kong, India, and Sri Lanka. Additional information can be obtained from Kallman Associates, 30 Journal Sq, Jersey City NJ 07306, (201) 653-3304.

October 24-25
The Second Annual New Jersey Microcomputer Show and Fleamarket, Holiday Inn (north) Convention Center, Newark International Airport, Newark NJ. This show will feature 75 commercial exhibitors and more than 100 vendors. User-group meetings will be held. Registration is $5 for both days. Contact Kengore Corporation, 3001 Rt 27, Franklin Park NJ 08823, (201) 297-2526.

October 25-30
The Forty-Fourth Annual Meeting of the American Association of Information Societies (ASIS), Washington Hilton Hotel, Washington DC. The theme for this meeting is "The Information Community: An Alliance for Progress." Among the topics to be addressed are information and creativity, information and society, and overcoming the barriers between information sciences. Contact ASIS, 1010 Sixteenth St, NW, Washington DC 20036, (202) 659-3644.

October 27-29
Computer Graphics 81, Regent Centre Hotel, London, England. Some of the topics to be covered are graphics systems: hardware and software; animation; image processing; simulation; and business and home graphics. An equipment exhibition will also be presented. For more information, contact Online Conferences Ltd, Argyle House, Northwood Hills, Middlesex, HA6 1TS, England.

October 29-November 1
Southeast Computer Show and Office Equipment Exposition, Atlanta Civic Center, Atlanta GA. For details, see October 15-18.

October 31-November 1
Computers in Ambulatory Medicine, Washington Sheraton, Washington DC. The Society for Advanced Medical Systems and the Society for Computer Medicine are sponsoring this conference. Basic and advanced tutorials on the fundamentals of medical computing will be featured along with technical sessions and presentations of papers. Fees are $115 for Society members and $165 for nonmembers. Contact SCM, 9650 Rockville Pike, Bethesda MD 20014, (301) 530-7120.

October 31-November 2
Annual Meeting of the American Society for Cybernetics, Washington Hilton Hotel, Washington DC. The theme for this meeting is "The New Cybernetics." A goal of the meeting will be to redefine the field of cybernetics and to provide a focus for the research efforts of the Society. Among the topics to be discussed are robotics, problem solving, pattern recognition, remote sensing, and communication networks. Contact Dr Laurence D Richards, Department of Administrative Science, Colby College, Waterville ME 04901, (207) 873-1131, ext 587.

November 1981

November 1-4
DPMA San Francisco '81, San Francisco Civic Center and Brooks Hall, San Francisco CA. This is DPMA's (Data Processing Management Association's) thirtieth

annual conference and business exposition. Contact the conference coordinator, DPMA, 505 Busse Hwy, Park Ridge IL 60068, (312) 825-8124.

November 5
Invitational Computer Conference, Amsterdam, Netherlands. The Invitational Computer Conference is a one-day computer show designed for quantity buyers. Exhibits and seminars are featured. For details, contact B J Johnson & Associates Inc, 2503 Eastbluff Dr, Suite 203, Newport Beach CA 92660, (714) 644-6037.

November 8-10
The Twelfth ACM North American Computer Chess Championship, Bonaventure Hotel, Los Angeles CA. A four-round, Swiss-style tournament is planned for this year's championship competition. In addition, a round-robin blitz tournament will be held. Games in this event proceed at a rate of 5 seconds per move. Belle, the current world champion, Chaos, Duchess, Nuchess, and L'Excentrique are among the programs being entered. For more information, contact Professor Monroe Newborn, School of Computer Science, McGill University, 805 Sherbrooke St West, Montreal, Quebec H3A 2K6, Canada.

November 9-10
Software Fair, Stouffers' Riverfront Towers, St Louis MO. This show is made up of software exhibitions from companies whose packages are in current use by members of the Southern and National Industrial Distributors Association. Distributors who are not members of these organizations can also exhibit their wares. Contact Don White or Tony Carroll, 1900 Arch St, Philadelphia PA 19103, (215) 564-3484.

November 9-11
ACM '81, Bonaventure Hotel, Los Angeles CA. This meeting will feature panel discussions on computers, software products in the 1980s, tutorials on computer-aided design, and a survey on the impact of robots on employment. Ray Bradbury and Dr Simon Ramo will speak. Computer exhibits and the North American Computer Chess Tournament will also be held. Contact ACM '81, POB 24059, Village Station, Los Angeles CA 90024, (213) 536-9735.

November 10-12
Midcon/81 Show and Convention, O'Hare Exposition Center and Hyatt Regency O'Hare, Chicago IL. Talks on microcomputers, energy, memory, communications, and consumer electronics will highlight this show. Contact Electronic Conventions Inc, 999 N Sepulveda Blvd, El Segundo CA 90245, (800) 421-6816; in California (213) 772-2965.

November 12
Invitational Computer Conference, Paris, France. For details, see November 5.

November 16-19
The Canadian Computer Show and Conference, International Centre of Commerce, Mississauga, Ontario Canada. For details, contact Reg Leckie, Industrial Trade Shows of Canada, 36 Butterick Rd, Toronto, Ontario, M8W 3Z8, Canada, (416) 252-7791.

November 17
Invitational Computer Conference, Milan, Italy. For details, see November 5.

November 17-19
Understanding and Using Computer Graphics, Atlanta GA. For details, see October 13-15.

November 19-20
Western Educational Computer Conference, San Francisco CA. Many of the computer-related talks at this conference will cover areas of interest to college instructors and administrators. For details, contact Ron P Langley, Data Processing Services, California State University-Long Beach, 1250 Bellflower Blvd, Long Beach CA 90840.

November 29-December 1
National Telecommunications Conference, New Orleans LA. This event is sponsored by the IEEE (Institute of Electrical and Electronics Engineers) and the New Orleans chapter of the Communications Society Conference Board. Some of the papers to be presented will discuss communications electronics, including software, terminals, theory, and data and computer communications. Contact G Allan Ledbetter, South Central Bell, 365 Canal St, Rm 1360, New Orleans LA 70140, (504) 528-7350.■

Software Received

This is a list of software packages that have been received by BYTE Publications during the past month. The list is correct to the best of our knowledge, but it is not meant to be a full description of the product or the forms in which the product is available. In particular, some packages may be sold for several machines or in both cassette and floppy-disk format; the product listed here is the version received by BYTE Publications.

This is an all-inclusive list that makes no comment on the quality or usefulness of the software listed. We regret that we cannot review every software package we receive. Instead, this list is meant to be a monthly acknowledgment of these packages and the companies that sent them. All software received is considered to be on loan to BYTE and is returned to the manufacturer after a set period of time. Companies sending software packages should be sure to include the list price of the packages and (where appropriate) the alternate forms in which they are available.

Apple

Desktop Plan II, for development and analysis of business plans for the Apple II. Floppy disk, $199.95. Personal Software, 1330 Bordeaux Dr, Sunnyvale CA 94086.

NORAD, a graphics arcade game for the Apple II and III. Floppy disk, $27.50. Western MicroData Enterprises Ltd, POB G 33, Postal Station G, Calgary, Alberta, T3A 2G1, Canada.

Robotwar, a graphics game using programmable robots for the Apple II. Floppy disk, $39.95. Muse, 330 N Charles St, Baltimore MD 21201.

Time Manager, a personal-information and organization system for the Apple II. Floppy disk, $149.95. Image Computer Products Inc, 615 Academy Dr, Northbrook IL 60062.

VisiCalc, the electronic spreadsheet for the Apple II. Floppy disk, $199.95. Personal Software, (see above address).

VisiDex, a data-base management system for the Apple II. Floppy disk, $199.95. Personal Software, (see above address).

VisiPlot, a graph-plotting system for the Apple II. Floppy disk, $179.95. Personal Software, (see above address).

VisiTrend and VisiPlot, a utility program that analyzes trends of graphs from VisiPlot for the Apple II. Floppy disk, $259.95. Personal Software, (see above address).

TRS-80

Armadillo Bug, utility program to manipulate machine-language routines for the TRS-80 Color Computer. Cassette, $12.95. Armadillo Software, POB 7661, Austin TX 78712.

Attack Force, a graphics arcade game for the TRS-80. Floppy disk, $19.95. Big Five Software, POB 9078, Van Nuys CA 91409.

Cosmic Fighter, a graphics arcade game for the TRS-80. Floppy disk, $19.95. Big Five Software, (see above address).

Faster, a utility program for TRS-80 Model I and II that speeds up the execution time of BASIC programs. Cassette, $29.95. ProSoft, POB 839, Hollywood CA 91603.

Galaxy Invasion, a graphics arcade game for the TRS-80. Floppy disk, $19.95. Big Five Software, (see above address).

Meteor Mission II, a graphics arcade game for the TRS-80. Floppy disk, $19.95. Big Five Software, (see above address).

Super Nova, a graphics arcade game for the TRS-80. Floppy disk, $19.95. Big Five Software, (see above address).

Tanjali, mind game comparing shapes and colors for the TRS-80 16 K Color Computer. Cassette, $29.95. Strawberry Software Inc, POB 743, Vashon Island WA 98070.

CP/M

Analiza, a computerized psychiatrist for the Commodore CP/M computer system. Eight-inch floppy disk, $35. SuperSoft Associates, POB 1628, 40 Main St, Suite 401, Champaign IL 61820.

SELECT, a CP/M word-processing system. Eight-inch floppy disk, $595. Select Information Systems, 919 Sir Francis Drake Blvd, Kentfield CA 94904.

Other Computers

Intruders and Airwar, graphics games for the Interact computer. Cassette, $10. Ernie Piette, 110 Hillcrest Rd, Pineville LA 71360.

Schedule, a utility program to help organize daily activities for the North Star computer. Floppy disk, $19.95. Azimuth Associates, POB 1636, Arlington VA 22210.

Shuttle Ascent Simulation, a graphics arcade game for the Atari 800. Cassette, $9.95. Starbound Software, POB 214, Cocoa Beach FL 32931.■

BYTE's Bugs

PR Problems

The letter entitled "Plot: North by Northwest," by William McWorter (May 1981 BYTE, page 14), was found to have a bug in line 10 of the program. The first "p" in line 10 should have been an "r." The line should read:

10 A$="rqvwrsvupqpwtstu"

Many thanks to all who wrote in with the correction.■

BYTE'S ARCADE

Big Five Software

Gregg Williams, Senior Editor

It may seem to many readers that BYTE's Arcade has concentrated on games for Apple and Atari computers. In a sense, this is natural; after all, both machines have excellent graphics, color, and sound capabilities—assets with which Radio Shack's TRS-80 Models I and III are less endowed. Given the coarse graphics, lack of color, and limited sound capabilities of the Radio Shack computers, what do they have in their favor?

The answer is: the ingenuity of Bill Hogue and Jeff Konyu.

Bill and Jeff comprise Big Five Software, a company that has developed an unequaled line of arcade-like software for the TRS-80. At the time of this writing, they had five games. Their first, Super Nova (an adaptation inspired by the Atari game, Asteroids), was reviewed in the May 1981 BYTE's Arcade (page 108). The three games I will describe here are Attack Force (similar to the arcade game Targ), Cosmic Fighter (similar to Cosmic Patrol), and Galaxy Invasion (similar to Galaxian). At present, they also have a game called Meteor Mission II, which resembles the arcade game Lunar Rescue.

Attack Force

Attack Force is my favorite game. The player drives a single ship in one of four directions around a "city" seven blocks square. Eight Ramships roam the avenues of the city with the sole intent of ramming and destroying your ship. You can fire missiles at the attackers, and are allowed to lose three ships before the game ends.

Several features make this a fascinating game. The *Flagship* (on the right edge of the screen in photo 1) can zap a Ramship and change it into a Flagship; or it can simply step into the boundaries of the city and start hunting your ship. A Flagship is especially dangerous because it can fire even when you're not in its line of sight. Once you clear the screen of all eight enemy ships, you get a stunning visual and aural display (that's right, this game has sound effects), bonus points, and a new set of enemy ships that are somewhat faster and net you more points when destroyed. Each score of 10,000 points gives you an extra ship (as in the other games described in this article), and, like all popular arcade games, the game gets harder and harder until you are inevitably overcome.

One feature that makes Attack Force particularly interesting is a practical joke that occurs at one point in

At a Glance

Name
Attack Force, Cosmic Fighter, Galaxy Invasion

Type
Arcade-style games

Manufacturer
Big Five Software
POB 9078-185
Van Nuys CA 91409
(213) 782-6861
(phone orders only)

Price
Model I/Model III cassette version, $15.95; Model I/Model III disk version, $19.95

Author
Bill Hogue

Format
Cassette or 5-inch floppy disk

Language
Z80 machine code

Computer
Radio Shack TRS-80 Model I or III with either 16 K bytes (cassette version), or 32 K bytes and one disk drive (disk version)

Documentation
Color leaflet plus documentation in program

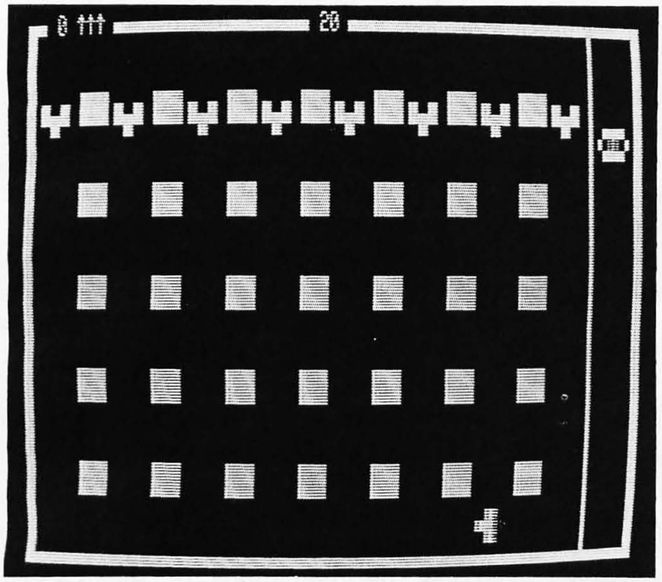

Photo 1: *Attack Force in progress.*

the game. I won't tell you what or when, so that you can be as surprised and delighted as I was.

Cosmic Fighter

Your ship appears at the bottom of the screen and you try to destroy a wave of alien ships that slowly drift from the top to the bottom of the screen in Cosmic Fighter. The alien missiles can move either straight or diagonally down the screen (see photo 2), and once you destroy the first wave (or let them go off the bottom of the screen), a new, more intelligent wave of aliens appears. Occasionally, a deadly Flagship that can fire from any angle appears—you have to destroy this one quickly. If you survive four waves of aliens, you have the chance to fight off the Flagship near your space station and then dock to get extra fuel for the next round. This time, however, the wave of enemy ships requires two hits per ship to destroy. This continues until you either lose three ships or run out of fuel.

Galaxy Invasion

Galaxy Invasion is a surprisingly faithful rendition of the popular Galaxian arcade game (which is itself a variation of the original Space Invaders). In Galaxy Invasion, you have a ship at the bottom of the screen that shoots up at a formation of enemy ships (see photo 3). The enemy ships don't move toward you, but instead send out attack groups that "peel off" the main formation, gliding diagonally down the screen and strafing the area they cover with missiles. The ever-present Flagship is just as dangerous in this game as it is in the others. A particularly nice feature is the different kinds of alien ships, all of which flap graphic "wings," both in the main formation and during strafing runs. In fact, it's difficult to imagine how Bill Hogue (who programs all the games) obtains such smooth movement of so many objects on the screen.

Galaxy Invasion lacks the color and the whining sound of attacking enemy ships, but is nonetheless amazingly close to the original arcade game that costs $.25 to play.

Common Features

All the games use the TRS-80's arrow keys for ship movement and the space bar for missile firing. Unlike

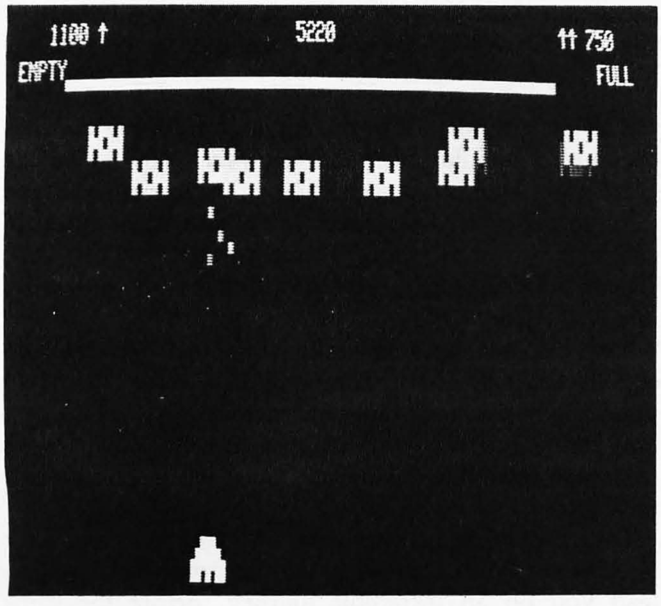

Photo 2: *Cosmic Fighter in progress.*

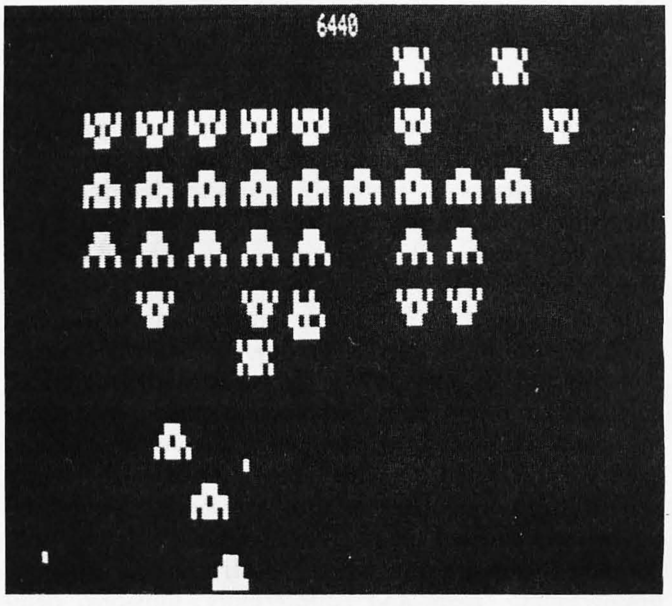

Photo 3: *Galaxy Invasion in progress.*

many microcomputer-based arcade games that exhibit a delay between a keypress and the reaction to it, these games always respond immediately to any keypress. All the games reviewed here also generate sound effects through the TRS-80 tape recorder and earphone (a standard method to get sound effects in a TRS-80). Although the sound is rough and scratchy, it adds immensely to the arcade quality of the games, the most frequent sound effects occurring every time you fire a missile or an explosion occurs.

Each of the games starts with a fancy billboard outlined in flashing lights, which also contains the names of the ten top scorers. (My only criticism is that for a home environment, ten names seem too many; five would give you more incentive to excel.) If you make one of the top scores, you put your initials into the billboard display.

From the beginning display you can either get a screen of instructions or start the game. All three games allow one or two people to play at the same time. A game may be aborted at any time.

Not only are these games fun to play—they are reasonably priced. At the time of this writing, two versions of each game were available (all supplied on cassette). One tape runs on both a TRS-80 Model I and a Model III with 16 K bytes of memory and costs $15.95. A disk version of each game is available for $19.95 (one game per disk); the disk will run on any Model I or Model III TRS-80 with 32 K bytes of memory and one disk drive.

Big Five also sells a joystick adapter ($39.95) that allows you to connect the rugged Atari joysticks to your TRS-80. All Big Five Software programs will respond to a joystick, and although I have not seen the adapter unit, I am confident it is of high quality.

Conclusions

- To the best of my knowledge, Attack Force, Cosmic Fighter, and Galaxy Invasion are the best arcade-style games available for the TRS-80 Models I and III. In fact, they represent some of the best examples of microcomputer game animation that I have ever seen. They are as challenging as their arcade counterparts and, as much as possible, overcome the limitations of the TRS-80 graphics.
- Each game is based on an arcade-type game but adds its own distinctive touches. All games use both sound and extensive graphics.
- The games are reasonably priced (especially in comparison to graphics games that range from $20 to $40 each) and are, in my opinion, a "best buy."■

The Prisoner

Bob Liddil, POB 66, Peterborough NH 03458

You're on an island with your every need provided for—everything, that is, except your freedom. The island's caretaker is watching and experimenting, his ultimate goal is to take away the last scrap of individuality you possess. It's you against the island. You are The Prisoner.

The Prisoner, by Edu-Ware Services Inc of Canoga Park, California, offers a unique, sometimes bizarre, recreation of an early 1970 s TV series that has attained cult status in recent years. To play the game, you assume the role of a disenchanted member of a covert intelligence agency. You're fed up with The Company—the whole system in general. After quitting the service, you're abducted and spirited off to The Island, an isolated, self-contained community where electronic surveillance, brainwashing, plots and counterplots, illusions, delusions, and confusions are the order of the day.

This program is not in the Adventure format that has become so popular over the last year. It is, in fact, a graphics-oriented, disk-accessing collection of fixed and randomized events that leaves you pounding your desk in endless frustration trying to make heads or tails of it. This is not necessarily bad because that is the program's intent.

The game is fundamentally a contest between two equally difficult goals. The computer wishes to obtain your resignation code (and, not incidentally, doesn't care how insane it drives you). You, on the other hand, wish to escape from The Island and must use every possible means to do so.

By studying the documentation carefully, you learn (well before booting the disk) that the program is going to lead you on an incredible journey. Before the game begins you are assigned a resignation code. The

documentation explains that this code is a condensation of your reasons for leaving The Company. When you awaken, the game begins in room #6, which contains a time-consuming invisible maze that is never the same twice. If you escape the maze, the machine greets you by asking you to identify yourself. Considering the twenty-minute invisible maze and the possible frustration of having to restart the game due to misinterpreting the screen—the tricks start coming right at the beginning—the inattentive player is in for rough sailing.

Once in the courtyard, the movement codes are different from those in the maze. A dead keyboard raises the frustration level before you realize that this is precisely what the author, in the guise of The Caretaker, or Master of the Island, is trying to do.

Subsequent scenarios are contained in twenty "buildings," each of which you may enter at any time. The trick is to survive and outwit the event once you're inside. For example, there is the Hospital, where an encounter with a "shrink" might be expected, and at the Town Hall you must play politics. There is a Bank, a Courthouse, a Church, and so on. All these locations are riddled with pitfalls and potential disasters. They are all designed to get you to throw in the towel and reveal your code.

The program uses an awesome mixture of graphics, sound, and text. There are high-resolution pictures with beeps and whistles and low-resolution pictures that confound you with simplicity. At times, portions of the program "jump loose" and seem to suffer a programming error. However, the program is not in error—it does this by design. It's a nightmare. The program doesn't do what you think it should.

The Prisoner is not for the easily frustrated, nor for those looking for a shoot-em-up arcade-type game. Instead, The Prisoner is complex beyond belief, nearly unbeatable, and at times irrational on purpose; careening through a calculated mind-warp, its sole function is to entertain.

If you follow the rules, trust your fellow man, or display anything less than a total commitment to anti-social, anti-island behavior, you will be hopelessly doomed to repeated failure.

Author David Mullich, a computer science student at California State University, Northridge, is a meticulous researcher with an artist's eye for depth and detail. In speaking about The Prisoner, he said: "I was sick and tired of all the arcade games and (conventional) Adventure games. They seemed to be imitations of each other."

As a youngster Mullich enjoyed *The Prisoner* on TV and found that, as a young man, the themes appealed to him. "I dreamed of doing a program on The Prisoner, and through Edu-Ware, I got the chance," he said.

At a Glance

Name
The Prisoner

Type
Epic nonclassical adventure game

Manufacturer
Edu-Ware Services Inc
22222 Sherman Way
Canoga Park CA 91303
(213) 346-6783

Price
$29.95

Author
David Mullich

Language
Applesoft BASIC

Computer
Apple II or Apple II Plus
Applesoft and 48 K bytes of memory

Documentation
12-page booklet

Audience
Puzzle solvers, adventure fans and students of the weird

Mullich's version of The Prisoner, though not untrue to the series, is a product of his vivid imagination. It will appeal to puzzle solvers and seekers of the bizarre. ■

Three Microcomputer LISPs

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"(TELL ME MORE ABOUT YOUR FAMILY)" With these immortal words, Joseph Weizenbaum's ELIZA program confronted the world with the power of artificial intelligence (AI) techniques. A good deal of that power comes from the expressiveness of the programming language LISP. Some sophisticated and powerful LISP software packages are now available for microcomputers. In this article, we review three LISPs, one of which is distributed with a modern version of ELIZA. The LISP packages are muLISP/muSTAR from The Soft Warehouse, Cromemco LISP from Cromemco Inc, and (T.(L.C)) from The LISP Company.

We have compared two basic issues: speed and functionality. In the LISPs reviewed, you will see that these two aspects are continually traded off: the slower LISP has more capabilities. The trade-off is more complex than in most languages, though. Due to the extreme flexibility of LISP, any feature of one LISP package can usually be emulated in another LISP package at the cost of increased run time.

LISP purchasers should realize that LISP is anything but a standardized language. Most LISPs are fairly idiosyncratic, representing many years of development, modification, and tailoring by their designers and users. The microcomputer-based LISPs are no exception. This can cause problems for new LISP users. A LISP you purchase may look quite unlike some of the dialects discussed in textbooks. Furthermore, many features of LISP are rarely discussed in texts, but they are quite useful for LISP programming.

Overview

muLISP successfully provides a useful artificial-intelligence development system to the microprocessor user community. It is billed as more than a LISP interpreter for the Z80, and it is a good bit more. It provides a reasonable set of LISP functions and special forms. It also supports the user with muSTAR, a development subsystem that makes entering and debugging code as painless as possible.

On the positive side, muLISP runs remarkably fast and allows for the creation and execution of fairly large LISP programs. On the negative side, some of the design decisions about error handling and type checking make debugging in muLISP harder than need be. In particular, muLISP provides almost no facilities to detect obvious nonsensical programs, and it does not allow a user to examine the data stack after an error or user interrupt. We like the ideas that motivated the muSTAR development subsystem, but are disappointed by some of the holes in the design. In particular, it is not easy to alternate between the high-efficiency environment and the development environ-

At a Glance

Name
muLISP/muSTAR-80 version 10/06/80

Type
Version of LISP programming language

Manufacturer
The Soft Warehouse
POB 11174
Honolulu HI 96828

Price
$200, from Lifeboat Associates
1651 Third Ave
New York NY 10028
(212) 860-0300;
$200, from Microsoft
10800 NE Eighth, Suite 819
Bellevue WA 98004
(206) 455-8080

Format
5-inch or 8-inch floppy disk

Language used
8080 or Z80 machine language

Computer needed
8080-, 8085-, or Z80-based computer with at least 20 K bytes of memory, running under a CP/M-compatible operating system

Documentation
100 pages, 8½ by 11 inches (22 by 28 cm), in a 3-ring binder

Audience
Students, educators, computer-language enthusiasts

ment. Also, the screen editor is not adaptable to all terminals. The example programs delivered with the system are interesting and give just a hint of the power of a microcomputer-based LISP system.

John Allen, who served as guest editor for the August 1979 BYTE LISP issue and wrote *Anatomy of LISP*, is the primary author of both the Cromemco and (T.(L.C)) LISP systems. Therefore these two LISPs are similar in most respects and will usually be discussed together. We believe that they are, in fact, different revisions of the same program. These LISPs are also a successful attempt to bring LISP into the world of microprocessors.

In many respects, Cromemco LISP and (T.(L.C)) LISP are more modern than muLISP. They lack an integrated development environment, but include many more intrinsic functions and data types, helpful type checking, and error detection. The extra functionality is provided at the expense of speed, but we feel that these LISPs still run acceptably fast. Our most important criticism is of the small, fixed-size stack. These LISPs do not allow one to write the powerful recursive functions that make LISP such a clean and elegant language. This is not necessarily a practical limitation since iteration is cleanly supported, but it is rather inelegant and unaesthetic.

Data Types in LISP

Most modern programming languages support a variety of data types. So do modern LISPs. In addition to the basic atoms, integers, lists, and property-list data types, different LISPs support "infinite-precision" integers, floating-point numbers, character strings, arrays, and Pascal-like records. For now, we ignore the fact that functions and special forms are also data types in LISP. We discuss them separately below. (*Special forms* are things that look like LISP functions, but have special conventions for their evaluation. COND is an example of an intrinsic special form.)

The inherent flexibility of the basic LISP data types allows almost any other data type to be emulated, but at a considerable price in execution speed and/or memory space. For example, we could emulate a character string as a list of single-letter atoms, but operations performed at the end of the "string" would be quite expensive. Furthermore, assuming a two-byte address, more than $4n$ bytes would be needed to store an n-character-length string. One would like a LISP implementation to directly support a variety of data types using machine-level data structures and operations.

At a Glance

Name
Cromemco LISP, version 1.06

Type
Version of LISP programming language

Manufacturer
Cromemco Inc
280 Bernardo Ave
Mountain View CA 94043
(415) 964-7400

Price
$295

Format
5-inch or 8-inch floppy disk

Language used
Z80 machine language

Computer needed
Z80-based computer with at least 48 K bytes of memory, running under Cromemco's CDOS or Cromix operating systems

Documentation
135 pages, 8½ by 11 inches (22 by 28 cm), in 3-ring binder; includes various CDOS manuals and a copy of *Artificial Intelligence Programming*

Audience
Students, educators, computer-language enthusiasts

Support of many data types does not imply strict type checking, as in Pascal. LISP style dictates that "reasonable" data-type conversions will happen automatically. For example, if an operation performed on two integer values yields a value not representable as an integer, one would expect LISP to return a floating-point or infinite-precision integer as the value.

Cromemco and (T.(L.C)) LISP support a richer set of data types than does muLISP. They support atoms, 14-bit integers, floating-point numbers, single characters, strings up to 256 characters long, lists, and property lists. Atoms in these LISPs can take only one value. This contrasts with many LISPs, including muLISP, which allow an atom to have two values, one interpreted as a function. Each atom does have an associated property list.

Cromemco and (T.(L.C)) LISP check data types fairly strictly. For example, single characters, denoted with a back slash ("\"), are not directly comparable to strings of length one, nor are they directly comparable to single-character atoms. Similarly, the string "123" is not directly comparable to the integer 123. Of course, functions are provided to convert between types. Cromemco and (T.(L.C)) LISP do provide facilities for building and supporting user-defined data types.

Cromemco and (T.(L.C)) LISP do have functions that behave differently depending on the type of argument passed in. For example, the ASCII function yields an integer when passed a character and a character when passed an integer:

```
(ASCII \ C) returns 67
(ASCII 67) returns \ C
```

The details of how these data structures are implemented are hidden from the users of (T.(L.C)) LISP. The "clever tricks" which this prevents are no loss to most programmers. The Cromemco LISP manual does discuss details of these data structures for use in writing external assembly-language functions.

muLISP supports atoms (called *names* in the manual), infinite-precision integers (actually, they must be in the range $\pm 256^{253}$), lists, and property lists. Each name can take two values—a value that is returned when the name appears as a function call, and a value that is returned in all other situations. Each name also has an associated property list. Strings are partially supported by allowing manipulation of the print names of atoms.

muLISP does almost no type checking. The manual discusses the implementation of the different data types very early, and some knowledge of this implementation is important in using the system. Many operations are defined for all data types, irrespective of whether this makes any sense. CAR and CDR, for example, will work perfectly well on numbers. This may be useful in some situations, but it often causes confus-

At a Glance

Name
(T.(L.C)) LISP version 1.07

Type
Version of LISP programming language

Manufacturer
The LISP Company
18215 Bayview Dr
Los Gatos CA 95030
(408) 353-2227

Price
$150

Format
5-inch or 8-inch floppy disk

Language used
Z80 machine language

Computer needed
Z80-based computer with at least 48 K bytes of memory, running under a CP/M-compatible operating system

Documentation
135 pages, 8½ by 11 inches (22 by 28 cm)

Audience
Students, educators, computer-language enthusiasts

ing results and subtle bugs. We feel the marginal extra functionality and generality provided in this way are only an invitation to poor code, obscure hacking, and subtle bugs. If it is necessary to explicitly manipulate an internal representation, there should be an explicit function to do this. Of course, muLISP saves both time and space by not checking data types.

User-Defined Special Forms

In a LISP system, one wishes to write things which look like functions, but behave differently. For example, we would like to write things like the standard LISP AND:

(AND *predicate-1 predicate-2 . . . predicate-n*)

AND evaluates each *predicate-i* in order, stopping if any predicate returns the value NIL (the standard LISP representation of the Boolean value *false*). There are two independent problems with writing AND as a standard LISP function. First, how do we pass an indefinite number of arguments, and second, how do we pass the parameters unevaluated? Special forms allow us to tell the system to treat the parameters in a special way. Below, we follow LISP convention and use the word *form* as a general term for both functions and special forms.

muLISP solves the problem of an indefinite-length parameter list with *no-spread forms,* in which there is only one formal parameter. (A formal parameter is a dummy variable in the form definition.) When a no-spread form is called, a list of all arguments is bound to that single formal parameter. The form uses this list of arguments in any way desired.

In muLISP, call-by-name forms are specified with NLAMBDA (for *N*o evaluation of *LAMBDA*) instead of

Listing 1: *Definition of AND-1 in muLISP.*

```
(LAMBDA (PRED-LIST)
      (COND
             ((NULL PRED-LIST) 1)
                    % we have reached the end of the predicates
                    % and all have evaluated non-NIL -
                    % return T.
             ((EVAL (CAR PRED-LIST))
                    (AND-1 (CDR PRED-LIST)))
                    % eval the next predicate, if non-NIL
                    % recur on the rest
             (T NIL)
                    % otherwise, the last predicate was false,
                    % exit with NIL
))
```

Listing 2: *A LISP function to print out the integers from 1 to N. The version in listing 2a is the function written in muLISP. The version in listing 2b is the function written in either Cromemco LISP or (T.(L.C)) LISP.*

(2a)

```
(LAMBDA (N)
      (SETQ COUNT 1)
      (LOOP
             (PRINT COUNT)
             ( (EQ COUNT N) N) % exit test
             (SETQ COUNT (PLUS COUNT 1))))
```

(2b)

```
(LAMBDA (N)
      (DO
             ( (COUNT 1 (PLUS COUNT 1)) )
                    ; Only one local variable, COUNT. It is
                    ; initialized to 1, and incremented on
                    ; each iteration
             ( (EQ COUNT N) N )
                    ; Only one exit test. It specifies an
                    ; exit with value N when count equals 101
             (PRINT COUNT)
                    ; The body contains only the PRINT
             ))
```

LAMBDA. Normal (LAMBDA) functions are call-by-value and evaluate each actual parameter, binding formal parameters to the values of the actual parameters. (Actual parameters are the expressions appearing as arguments to a function call.) In a call-by-name function, the formal parameters are bound directly to the actual parameters. If evaluation is desired for any of these parameters, it is explicitly specified with EVAL.

We can write a muLISP version of AND defined as:

```
(NLAMBDA PRED-LIST
    (AND-1 PRED-LIST))
```

Because AND is a call-by-name no-spread form, all its actual parameters are gathered, unevaluated, into a list that is bound to PRED-LIST. AND-1 is called with PRED-LIST as its single parameter. AND-1 is a call-by-value spread function. AND-1 is then defined as shown in listing 1.

In summary, muLISP supports two types of forms—call-by-value and call-by-name—and two parameter-binding styles—spread and no-spread. All four combinations are permitted and useful. muLISP forms are compiled in a way that is largely transparent to the user.

Cromemco and (T.(L.C)) LISP also allow both call-by-value and call-by-name (referred to as "call-unevaluated" in the manual) forms. Additionally, LISP macros are supported. A LISP macro has only one parameter, which is bound to the complete text of the expression that calls the macro. For example, consider a macro TEST, which is called with the following expression:

```
(TEST JOE (CAR A) 5)
```

The formal parameter of TEST would be bound to the expression:

```
(TEST JOE (CAR A) 5)
```

The macro body is then free to manipulate the original expression with the full power of LISP. The

Issue Discussed	Cromemco and (T.(L.C)) LISP	muLISP
Cost	$295-Cromemco *$150-(T.(L.C))	$200
Data types supported	*Atoms, integers, floating-point, characters, strings, lists, property lists	Atoms, strings, infinite integers, lists, property lists
Type checking	*yes	no
Number of intrinsic functions	*145-Cromemco; 144-(T.(L.C))	71
Parameter options	*Optional, auxiliary, rest	Spread or no-spread
Special forms	*Macros, read-macros "call-by-unevaluated"	"Call-by-name"
Control flow	DO, PROG1, PROGN, COND, AND, OR, CATCH, THROW	LOOP, implicit sequencing, PROG1, COND, implicit conditional, AND, OR
Input and output at the terminal	Allows backspace	*Allows backspace, retype line, abort line
Program saving and restoring	Text files, absolute memory image, auto-load	Text files and compressed internal image files
Program-controlled input and output	*Well done, I/O functions work on strings	Well done
Space management	Dynamic space allocation for all data types, the stack is fixed in size and too small	*Dynamic space allocation for all data types and the stack
User environment	Simple environment for developing, debugging, and executing programs; ability to examine the data stack after errors, extensive error checking; tracing abilities	Separate development (muSTAR) and execution (muLISP) environments; no ability to examine the data stack after errors; too little error checking; muSTAR includes a screen editor; tracing abilities; source code for muSTAR included
Linking to assembly language	Cromemco-well documented and supported (T.(L.C))-not supported	Possible but poorly documented
Documentation/library software	Clear manual suitable for beginners; many examples	Clear user's manual; too terse and formal for beginners; includes several utilities and games
Speed	Adequate	*4 to 7 times faster than the others

Table 1: *Comparison chart for the versions of LISP reviewed. This table summarizes the differences discussed in the text. For each issue discussed, an asterisk (*) denotes the LISP the reviewers consider to be superior. The absence of an asterisk denotes a tie among the three versions.*

Expression evaluated in TESTER loop	(T.(L.C)) counts	Cromemco counts	muLISP counts
NIL	8122	8061	31260
LC	265	258	1667
DC	408	409	2100
BIGCAR	556	549	4316
BIGCDR	555	552	4200
'(HAS-AS-MEMBER-I 'B LONG1)	119	119	704
'(HAS-AS-MEMBER-R 'B LONG1)	79	79	367
'(REMOVE-ELEMENT-I 'B LONG41)	84	85	24
'(REMOVE-ELEMENT-R 'B LONG41)	64	66	318
'(HOW-RELATED 'FRODO-B 'BILBO-B)	3	3	16

Notes:

- All of the above expressions were evaluated as many times as possible in 30 seconds (60 seconds for the call to HOW-RELATED). The counts represent how many complete evaluations occurred in that time.
- The counts given represent an average of three separate trials, except for the Cromemco counts, which represent one trial. The one Cromemco trial was run to verify the similarity between (T.(L.C)) and Cromemco LISP,as explained in the text.
- muLISP performs particularly slowly with REMOVE-ELEMENT-I because this function uses APPEND, which is not intrinsic to muLISP. To run REMOVE-ELEMENT-I we used the recursive version of APPEND supplied in the muLISP utility library. The use of an interative APPEND would improve the performance shown.
- These tests were run on a Cromemco C3 Z80-based system with 64 K bytes of memory running at 4 MHz.
- The amount of available memory influences these results in two opposing ways. More memory means fewer garbage collections, but the garbage collections that do occur last longer.

Table 2: *Timing results for the LISP benchmark programs. For details on how this table was compiled, see the text box "Notes on LISP Benchmarks."*

value computed, however, is then itself evaluated, yielding the final value of the macro call. Often a problem is best solved by manipulating the text of a form's call. Macros allow this manipulation in a clean way. Macros are particularly suitable for hiding data-structure implementations.

Cromemco and (T.(L.C)) LISP allow a very general formal-parameter-list specification for call-by-value functions. In particular, one can specify *regular* parameters, *optional* parameters, *auxiliary* parameters, and a *rest* parameter. Optional parameters are bound to a specified default value if they are not specified as an actual parameter. Auxiliary parameters are local variables to the function, and they are specified with an initialization value. The rest parameter is bound to a list of all actual parameters not bound to a formal parameter of some other type. This is more flexible than the no-spread parameter of muLISP because some actual parameters can be required even though the total number is indefinite. The call-by-name and macro forms of Cromemco and (T.(L.C)) LISP also allow the definition of auxiliary parameters. We found this sophisticated parameter list to be quite useful and concise once we were familiar with it.

LISP Control Structures

Because LISP uses the same representation for data and programs, the difference between control structures and data structures becomes blurred. For example, one function may construct a list which is then evaluated as a function call. We have done this in the function BUILD-LONG-CONS in listing 3. For the purpose of this review, we consider any construct that affects the order of expression evaluation to be a control structure. LISP easily allows the definition and integration of new control structures that reflect the needs of a particular problem. In particular, the LISPs reviewed here allow one to create new control structures using the special forms described above. This means that if you like a control structure in one LISP, you can usually emulate it in another.

Sequencing Control Structures

The simplest control structure allows one to evaluate a sequence of expressions. In muLISP, sequential evaluation is implied by putting several expressions to be evaluated into a list. For example:

```
((PLUS 3 4) (CAR (QUOTE (A B)))
(SETQ  Z  6))
```

returns:

```
(7 A 6)
```

and binds 6 to the atom Z. Also provided is the PROG1 form which returns the value of the first expression it evaluates, but also evaluates

Text continued on page 396

Listing 3: *Benchmark functions for versions of the LISP programming language. These functions are used either to build expressions used in the timing benchmarks or as functions to be benchmarked. BUILD-LONG-CONS, BUILD-DEEP-CONS, and NESTED-APPLICATION are used to build expressions that test CONS, CAR, and CDR. Listing 5 shows how they are used. REMOVE-ELEMENT and HAS-AS-MEMBER represent archetypical LISP functions. They are tested in both a recursive and an iterative form. These functions are written in a neutral "standard" LISP, except for the iterative versions of REMOVE-ELEMENT and HAS-AS-MEMBER. Comments are delimited with braces ({ }). See also table 2 and the text box labeled "Notes on LISP Benchmarks."*

```
------------------------------------------------------------------------
build-long-cons

    { Builds a CONS expression which, when evaluated, will
      produce a list LENGTH long of ELEMENT.  Example:
        (BUILD-LONG-CONS 5 'A) returns
        (CONS 'A (CONS 'A (CONS 'A (CONS 'A (CONS 'A NIL)))))
    }
        (lambda (length element)
                (cond ((zerop length) nil)
                      (t (list 'cons
                               (list 'quote element)
                               (build-long-cons (difference length 1)
                                                element))))))
------------------------------------------------------------------------
build-deep-cons

    { Builds a CONS expression which, when evaluated, will produce
      a list DEPTH deep with the innermost list containing
      ELEMENT.  Example:
        (BUILD-DEEP-CONS 5 'A) returns
        (CONS (CONS (CONS (CONS (CONS 'A NIL) NIL) NIL) NIL) NIL)
    }
        (lambda (depth element)
                (cond ((zerop depth) (list 'quote element))
```

Listing 3 continued:

```
                    (t (list 'cons
                             (build-deep-cons (difference depth 1)
                                              element)
                             nil))))
---------------------------------------------------------------------
nested-application

   { Builds an expression which, when evaluated, will apply
     FUNCTION to ARG, then FUNCTION to the results, then to
     those results, etc. for a total of LENGTH times.  Example:

       (NESTED-APPLICATION 'CAR 5 '((((((A)))))) ) returns
       (CAR (CAR (CAR (CAR (CAR ((((((A)))))) ) ) ) ) )
   }

       (lambda (function length arg)
               (cond ((zerop length) arg)
                     (t (list function
                              (nested-application
                               function
                               (difference length 1)
                               arg)))))
---------------------------------------------------------------------
has-as-member-r

   { Returns T if ELEMENT appears in LST.  This is the recursive
     version of the function. }
       (lambda (element lst)
               (cond ((null lst) nil)
                     ((eq element (car lst)) t)
                     (t (has-as-member element (cdr lst)))))
---------------------------------------------------------------------
remove-element-r

   { Returns a copy of LST with all occurences of ELEMENT
     deleted.  This is the recursive version. }
       (lambda (element lst)
               (cond ((null lst) nil)
                     ((eq element (car lst)) (remove-element-r
                                               element
                                               (cdr lst)))
                     (t (cons (car lst)
                              (remove-element element (cdr lst))))))
---------------------------------------------------------------------
has-as-member-i-muLISP
  { The muLISP iterative version of HAS-AS-MEMBER. }
       (lambda (element lst)
               (setq cdr-lst lst)
               (loop ((null cdr-lst) nil)
                     ((eq (car cdr-lst) element) t)
                     (setq cdr-lst (cdr cdr-lst))))
---------------------------------------------------------------------
remove-element-i-Cromemco-tlc
  { The Cromemco/(T.(L.C)) iterative version of REMOVE-ELEMENT. }
       (lambda (element lst)
               (do ((front nil
                           (if (eq element (car back))
                               (append front (list (car back)))
                               front))
                    (back lst (cdr back)))
                   (((null back) front))))
---------------------------------------------------------------------
```

Text continued from page 394:
all other expressions in order. For example:

```
(PROG1 (PLUS 3 4) (CAR (QUOTE
(A B))) (SETQ  Z  6))
```

returns 7, but also executes the CAR, throwing away the result, and binds 6 to the atom Z.

The implicit sequence evaluation, while convenient, is often confusing and error-prone. Quite often, incorrect functions evaluate without an error because there is almost always a legal interpretation of any expression. We feel this disadvantage outweighs the convenience of the implicit form.

Cromemco and (T.(L.C)) LISP provide PROG1 as well as a PROGN special form. PROGN evaluates its expressions in sequence, like PROG1, but returns the value of the *last* expression evaluated.

Conditional Control Structures

The standard LISP form for expressing conditionality is COND. In muLISP, COND is implied in any list of expressions. If any element of the list is of the form:

(*predicate expression*)

and *predicate* evaluates to non-NIL, then control exits from the outer list with the value of *expression*. Like the implicit sequence evaluation, this feature trades readability and ease of debugging for conciseness and speed. Of course, an explicit COND is also available in muLISP.

The COND form is augmented with an IF form in Cromemco and (T.(L.C)) LISP:

(IF *predicate expression-1*
    expression-2 . . . expression-n)

If *predicate* is true, *expression-1* is evaluated and its value is returned. Otherwise, *expression-2* through *expression-n* are evaluated, and the results of evaluating *expression-n* are returned.

All three LISPs provide the conditional logical operators AND and OR:

(AND *predicate-1 predicate-2 . . . predicate-n*)
(OR *predicate-1 predicate-2 . . . predicate-n*)

If any *predicate-i* evaluates to NIL for AND, or other than NIL for OR, the form immediately returns with that value, evaluating no other *predicate-i*.

Recursion and Iteration

LISP is one of the cleanest languages in which to express a recursive solution to a problem. LISP programs that use only recursion are clean, elegant, and very simple to debug because there are no global variables or side effects. Unfortunately, purely recursive LISP programs are usually too slow. Typically, when an application program is found to be too slow, a few functions are taking most of the time. (In our genealogy program in listing 4, SONG-1 and SING-1 are the critically slow functions.) Once these functions are found, they can each be optimized, usually by making them iterative. Good LISPs must provide clean iterative structures which localize any use of side effects and easily replace recursive structures. All LISPs reviewed here have good iteration constructs.

The LOOP iteration construct of muLISP allows any sequence of expressions within the loop body. If any expressions are of the form:

(*predicate expression*)

then *predicate* is evaluated on each iteration of the loop. If it is non-NIL, the LOOP returns with the value of *expression*.

Consider the problem of writing a function to print out the integers from 1 to *n*, returning the value *n*. In muLISP this would be written as shown in listing 2a.

The DO iteration construct of

Text continued on page 404

Notes on LISP Benchmarks

The timing benchmarks were designed to test the speed of CAR, CDR, and CONS, the workhorse functions of LISP; the speed of some simple but "archetypical" LISP functions, in both recursive and iterative form; and the speed of a reasonably large LISP program with several modules. Basically, the benchmarks were performed in an environment created by defining the functions shown in listing 3 and evaluating the expressions shown in listing 4.

To test CAR, CDR, and CONS, we built long nested expressions that invoke only these functions. This is done with the functions BUILD-LONG-CONS, BUILD-DEEP-CONS, and NESTED-APPLICATION in listing 3.

We chose REMOVE-ELEMENT and HAS-AS-MEMBER as the "archetypical" LISP functions. In listing 3, we show the recursive versions of each and a sample iterative version of each. Since iteration constructs differ widely among LISPs, we tailored an iterative version for each LISP to be benchmarked.

Finally, listing 4 shows the genealogy program we developed as our full-size LISP program. This program allows one to enter family-tree information through the functions BORN, MARRIED, and FIRST-BORN (FIRST-BORN is used when the parents of the new entry are unknown). The family tree is queried by calling the function HOW-RELATED with two names. This program has three principal components. The first group of functions know about kinship. These functions use another set of functions that perform a breadth-first search through a family tree. Finally, the family tree is implemented with a set of graph-manipulating functions based on the language GRASPER.

In listing 5, we entered parts of the BAGGINS and TOOK family trees. Our test then involved asking how Bilbo Baggins and Frodo Baggins are related. These family trees can be found in appendix C of J R R Tolkien's Return of the King.

Timing is actually done by counting the number of times a given expression will be evaluated in a fixed time period. The function TESTER in listing 5 performs the evaluation and counting repeatedly until it is interrupted after a fixed time period. The count is then examined. Note that before entering the main tester loop we always perform a garbage collection.

Listing 4: *A genealogy program written in LISP. This program is intended to test the LISPs on a moderate-sized program with several modules. It allows one to enter family-tree information through the functions BORN, MARRIED, and FIRST-BORN (FIRST-BORN is used when the parents of the new entry are unknown). The system is initialized with the function CREATE-UNIVERSE. The program has three levels: a group of functions that know about kinship, another group of functions that perform a breadth-first search, and finally a set of graph-manipulation functions that implement the family-tree data structure.*

```
-------------------------------------------------------------------------
how-related
   { Describes how P1 is related to P2. First we check the simple
     cases that P1 is the same as P2 and that P1 is P2's spouse.
     Otherwize, we call DESCRIBE-RELATION after computing the
     path in the family tree between P1 P2. }
        (lambda (p1 p2)
                (cond ((eq p1 p2) (list 'same))
                      ((eq p1 (spouse-of p2)) (list
                                               (sex-of-spouse p1)))
                      (t (describe-relation p1
                                            p2
                                            (find-path-between p1 p2))))))
-------------------------------------------------------------------------
describe-relation
   { Based on a legal connecting path through the family tree,
     describes how P1 is related to P2.  PATH-UP-AND-DOWN is a
     list with the distance up from P1 to the lowest common
     ancestor and the distance down to P2 from the lowest
     common ancestor.  We use a LAMBDA binding to cut this
     list into components D1 and D2.  If either D1 or D2 is
     zero, the relationship is direct.  Other cases are dealt with
     by NOT-DIRECT-RELATIONS. }
        (lambda (p1 p2 path-up-and-down)
                (cond ((null path-up-and-down) '(not
                                                 related
                                                 by
                                                 blood))
                      (t ((lambda (d1 d2)
                                  (cond ((eq d1 0)
                                         (direct-ancestor p1 d2))
                                        ((eq d2 0)
                                         (direct-descendent p1 d1))
                                        (t (not-direct-relations
                                            p1
                                            p2
                                            d1
                                            d2))))
                          (car path-up-and-down)
                          (cadr path-up-and-down)))))
-------------------------------------------------------------------------
direct-descendent
   { The relationship is known to be child, grandchild, great
     grandchild, or etc.  This function invokes choosing the
     right relation name by sex - son or daughter, and the
     right number of greats. }
        (lambda (younger distance)
                (add-grand-greats (sex-of-child younger) distance))
-------------------------------------------------------------------------
direct-ancestor
   { The relationship is known to be parent, grandparent, great
     grandparent, or etc.  This function invokes choosing the
     right relation name by sex - father or mother, and the
     right number of greats. }
        (lambda (older distance)
                (add-grand-greats (sex-of-parent older) distance))
```

Listing 4 continued on page 398

Listing 4 continued:

```
-----------------------------------------------------------------------
not-direct-relations
   { Based on the distances D1 and D2, determine the relation
     P1 and P2.  If D1 and D2 are both one, then P1 and P2 are
     siblings.  If D1 equals D2, and both are greater than one,
     then P1 is P2's nth cousin, where n is D1 (or D2) minus one.
     Finally, if D1 is not equal to D2, and both are greater than
     one, P1 is P2's Nth cousin, M removed.  N is D1 minus 1, and M is
     the absolute value of the difference between D1 and D2.
   }
       (lambda (p1 p2 d1 d2)
               (cond ((and (eq d1 1) (eq d2 1)) (list
                                                 (sex-of-sibling p1)))

                     ((eq d1 d2) (list (difference d1 1)
                                       'cousin))
                     ((eq d1 1) (ancestors-sibling p1 d2))
                     ((eq d2 1) (siblings-descendent p1 d1))
                     (t (list (difference d1 1)
                              'cousin
                              (abs (difference d2 d1))
                              'removed))))
-----------------------------------------------------------------------
find-path-between
   { To find a path between P1 and P2 we use a breadth first search.
     Starting at P1 we look for P2 one step away, then two
     steps away, etc.  The BREADTH-FIRST-SEARCH is passed a list
     of unexpanded nodes and a goal.  The unexpanded nodes are
     lists with the following information:
       -a person to be checked next
       -the distance traveled up to get to this person
       -the distance traveled down to get to this person
       -the last person visited before this person
     We start with a P1 node and initial values on the unexpanded
     list. }
       (lambda (p1 p2)
               (breadth-first-search (list (list p1
                                                 0
                                                 0
                                                 'the-great-unknown))
                                      p2))
-----------------------------------------------------------------------
breadth-first-search
   { We take the first unexpanded node of the unexpanded list.
     if it represents the goal node, we return its accumulated
     distances.  Otherwize, we check its relations to see who
     needs to be added as nodes to the unexpanded list. }
       (lambda (unexpanded goal-node)
               (cond ((null unexpanded) nil)
                     (t ((lambda (next)
                                 (cond ((eq (node-of next)
                                            goal-node)
                                        (list (dist-up-of next)
                                              (dist-down-of next)))
                                       (t (check-relatives
                                           next
                                           goal-node
                                           (cdr unexpanded)))))
                         (car unexpanded)))))
-----------------------------------------------------------------------
check-relatives
```

Listing 4 continued:

```
    { Appends new nodes on the end of the unexpanded list.  By
      putting them on the end we get a breadth first search.
      These new nodes are built by BUILD-NEW-UNEXPANDED which
      uses various information from the last node expanded.
    }
         (lambda (last-expanded person unexpanded)
                 (breadth-first-search (append unexpanded
                                               (build-new-unexpanded
                                                (node-of
                                                 last-expanded)
                                                (dist-up-of
                                                 last-expanded)
                                                (dist-down-of
                                                 last-expanded)
                                                (where-of
                                                 last-expanded)))
                                       person))
-----------------------------------------------------------------------
 build-new-unexpanded
    { Finds all the neighbors of the node last expanded and
      builds unexpanded nodes for them.  If we have not
      yet started down in the tree (D-DOWN equals 0),
      we can also build unexpanded nodes from parents of the
      node last expanded.  In each case we will note
      the new distances and the node last expanded. }
         (lambda (node d-up d-down from)
                 (append (make-unexpanded (song node 'child)
                                          node
                                          d-up
                                          (plus d-down 1)
                                          from)
                         (cond ((eq d-down 0) (make-unexpanded
                                               (song
                                                node
                                                'parent)
                                               node
                                               (plus d-up 1)
                                               d-down
                                               from))
                               (t nil))))
-----------------------------------------------------------------------
make-unexpanded
   { Given a list of nodes and information about how we got
     to those nodes, builds unexpanded nodes for the
     breadth first search.  We do not make an unexpanded node
     for THE-GREAT-UNKNOWN or for the place we were at two steps
     ago.  In this way we avoid infinitely looping through
     the family tree. }
        (lambda (node-list from d-up d-down from-from)
                (cond ((null node-list) nil)
                      ((or (eq (car node-list)
                               'the-great-unknown)
                           (eq (car node-list) from-from))
                       (make-unexpanded (cdr node-list)
                                        from
                                        d-up
                                        d-down
                                        from-from))
                      (t (cons (list (car node-list)
                                     d-up
                                     d-down
```

Listing 4 continued on page 400

Listing 4 continued:

```
                                   from)
                              (make-unexpanded (cdr node-list)
                                               from
                                               d-up
                                               d-down
                                               from-from)))))
-----------------------------------------------------------------------
node-of
   { This and the next three functions select sub fields of an
     unexpanded node. }
        (lambda (unexpanded-entry) (car unexpanded-entry))
-----------------------------------------------------------------------
dist-up-of
        (lambda (unexpanded-entry) (cadr unexpanded-entry))
-----------------------------------------------------------------------
dist-down-of
        (lambda (unexpanded-entry) (caddr unexpanded-entry))
-----------------------------------------------------------------------
where-of
        (lambda (unexpanded-entry) (cadddr unexpanded-entry))
-----------------------------------------------------------------------
born
   { Allows a user to declare that PERSON of sex SEX was born
     to PARENT1 and PARENT2.  Various graph primitives are
     used to link the new arrival into the family tree.  These
     primitives are explained below. }
        (lambda (person parent1 parent2 sex)
               (progn (cun person)
                      (bun person sex)
                      (cip person 'child parent1)
                      (cip person 'child parent2)
                      (cop person 'parent parent1)
                      (cop person 'parent parent2)
                      person))
-----------------------------------------------------------------------
married
   { Allows a user to declare that PERSON1 and PERSON2 were
     married.  The graph processing primitives used to do
     this are explained below. }
        (lambda (person1 person2)
               (progn (cap person1 'spouse person2)
                      (list person1 person2)))
-----------------------------------------------------------------------
add-grand-greats
   { Adds the right NUMBER of "grand"s and "great"s to the
     basic relationship name ONE-CASE. }
        (lambda (one-case number)
               (cond ((eq number 1) (list one-case))
                     ((eq number 2) (list 'grand one-case))
                     (t (cons 'great
                              (add-grand-greats one-case
                                                (difference
                                                 number
                                                 1))))))
-----------------------------------------------------------------------
add-greats
   { Add the right NUMBER of "great"s to the basic relationship
     name ONE-CASE.  Note that "grand"s are not used.  This
     is more common usage for great uncles and aunts. }
        (lambda (one-case number)
               (cond ((eq number 1) (list one-case))
                     (t (cons 'great
```

Listing 4 continued:

```
                                        (add-greats one-case
                                                      (difference number 1))))))
--------------------------------------------------------------------------------
ancestors-sibling
   { Builds up the appropriate kind of uncle or aunt based
     on the sex of UNCLE-OR-AUNT and the DISTANCE. }
        (lambda (uncle-or-aunt distance)
                (add-greats (sex-of-uncle-or-aunt uncle-or-aunt)
                            (difference distance 1)))
--------------------------------------------------------------------------------
siblings-descendent
   { Builds up the appropriate kind of niece or nephew based
     on the sex of NIECE-OR-NEPHEW and the DISTANCE. }
        (lambda (niece-or-nephew distance)
                (add-greats (sex-of-niece-or-nephew niece-or-nephew)
                            (difference distance 1)))
--------------------------------------------------------------------------------
spouse-of
   { Follows NODEs spouse link using a graph processing primitive. }
        (lambda (node)
                (car (song node 'spouse)))
--------------------------------------------------------------------------------
sex-of-child
   { This and the next 6 functions chose the appropriate relation
     name based on the PERSONs name.  They all pass a FEMALE-CHOICE
     and a MALE-CHOICE to CHOOSE-BY-SEX, which actully looks
     up the sex of PERSON and returns a choice. }
        (lambda (person)
                (choose-by-sex person 'daughter 'son))
--------------------------------------------------------------------------------
sex-of-parent
        (lambda (person)
                (choose-by-sex person 'mother 'father))
--------------------------------------------------------------------------------
sex-of-spouse
        (lambda (person)
                (choose-by-sex person 'wife 'husband))
--------------------------------------------------------------------------------
sex-of-uncle-or-aunt
        (lambda (person)
                (choose-by-sex person 'aunt 'uncle))
--------------------------------------------------------------------------------
sex-of-niece-or-nephew
        (lambda (person)
                (choose-by-sex person 'niece 'nephew))
--------------------------------------------------------------------------------
sex-of-sibling
        (lambda (person)
                (choose-by-sex person 'sister 'brother))
--------------------------------------------------------------------------------
choose-by-sex
        (lambda (person female-choice male-choice)
                (cond ((eq (sex-of person) 'female)
                       female-choice)
                      (t male-choice)))
--------------------------------------------------------------------------------
sex-of
   { Uses graph processing primitives to look up the sex of PERSON }

        (lambda (person) (vun person))
--------------------------------------------------------------------------------
first-born
```

Listing 4 continued on page 402

Listing 4 continued:

```
    { Useful to enter a person whose parents are not known. }
        (lambda (person sex)
                (progn (cun person)
                       (bun person sex)))
-----------------------------------------------------------------------
create-universe
    { Sets up the two global lists used by the graph processing
      system. The UNIVERSE-NODE-LIST is a list of all the nodes
      in the system. Here, a node is a person in the family tree.
      The UNIVERSE-EDGE-LIST holds all the connections between
      nodes in the system. These are kept as triples of (node1
      edge node2) to represent an edge called EDGE pointing
      from NODE1 to NODE2. In this case the edges will be
      familial relations. This function also creates THE-
      GREAT-UNKNOWN who is related to no one. }

        (lambda nil
                (progn (setq universe-node-list nil)
                       (setq universe-edge-list nil)
                       (cun 'the-great-unknown)))
-----------------------------------------------------------------------
cun
    { Creates a node in the universe by updating the
      UNIVERSE-NODE-LIST. }

        (lambda (node)
                (progn (setq universe-node-list (cons
                                                 node
                                                 universe-node-list))
                       node))
-----------------------------------------------------------------------
bun
    { Binds a value to a node in the universe. Node values are
      kept on the node's property list, under the indicator VALUE.
      Here the value of a node is the persons sex. }

        (lambda (node value) (putprop node value 'value))
-----------------------------------------------------------------------
vun
    { Get the value of a node in the universe. The converse of bun }

        (lambda (node) (getprop node 'value))
-----------------------------------------------------------------------
sun
    { Set of all nodes in the universe. This is just the
      UNIVERSE-NODE-LIST itself.}

        (lambda nil universe-node-list)
-----------------------------------------------------------------------
cip
    { Create an inpointing edge. This just reverses the arguments
      passed to it and calls add-triple which does the work. }

        (lambda (node1 edge node2)
                (progn (add-triple node2 edge node1) node1))
-----------------------------------------------------------------------
cop
    { Creates an outpointing edge, from node1 to node2. As above
      but without the reversal of arguments. }

        (lambda (node1 edge node2)
```

Listing 4 continued:

```
                (progn (add-triple node1 edge node2) node1))
-----------------------------------------------------------------------
cap
   { Creates a pair of edges one in each direction. }

        (lambda (node1 edge node2)
                (progn (cip node1 edge node2) (cop node1 edge node2)))
-----------------------------------------------------------------------
sing
   { Set of nodes who point to this node via edges of type EDGE.
     here we just set up the call for the recursive helper
     function. }

        (lambda (node1 edge) (sing-1 node1 edge universe-edge-list))
-----------------------------------------------------------------------
sing-1
   { This is the recursive version of the helper function for sing.
     Since this function and song-1 below are the two workhorses
     of the graph functions, we used iterative versions in the
     timing tests. The recursive versions are shown here for
     clarity. The function CDRs down U (initaly the UNIVERSE-
     EDGE-LIST) looking for a triple of the form (node1
     edge node2) where node2 equals N1 and edge equals E.
     Whenever it finds such  a triple it CONSes the node1 element
     to the set of nodes to be returned. This is just the set
     of nodes which have edges of type E which point to N1. }

        (lambda (n1 e u)
                (cond ((null u) nil)
                      ((and (eq (cadar u) e) (eq (caddar u) n1))
                       (cons (caar u) (sing-1 n1 e (cdr u))))
                      (t (sing-1 n1 e (cdr u)))))
-----------------------------------------------------------------------
song
   { Set of nodes which NODE1 points to via an edge of type EDGE.
     This is just like sing above, except it calls song-1. }

        (lambda (node1 edge) (song-1 node1 edge universe-edge-list))
-----------------------------------------------------------------------
song-1
   { Identical to sing-1 above except here we are matching
     node1 and edge of the triple and returning node2. }

        (lambda (n1 e u)
                (cond ((null u) nil)
                      ((and (eq (caar u) n1) (eq (cadar u) e))
                       (cons (caddar u) (song-1 n1 e (cdr u))))
                      (t (song-1 n1 e (cdr u)))))
-----------------------------------------------------------------------
dun
   { Destroys a node in the universe by removing it from
     the UNIVERSE-NODE-LIST and the UNIVERSE-EDGE-LIST.
     the real work is done by retriples and remember below. }

        (lambda (node)
                (progn (setq universe-node-list (remember
                                                 node
                                                 universe-node-list))
```

Listing 4 continued on page 404

Listing 4 continued:

```
                                        (setq universe-edge-list (retriples
                                                                   node
                                                                   universe-edge-list))
                                        node))
------------------------------------------------------------------------------------
remember
   { Remove all ocurrences of NODE in LIST. This is just
     a simple recursive constructor function. It CDRs down the
     list and CONSes together all elements which are not NODE. }

         (lambda (node list)
                 (cond ((null list) nil)
                       ((eq (car list) node) (remember
                                                node
                                                (cdr list)))
                       (t (cons (car list) (remember node (cdr
list))))))
------------------------------------------------------------------------------------
retriples
   { Remove all triples from U (the UNIVERSE-EDGE-LIST) where
     N is either node1 or node2. This eliminates any edges
     which point to or from node N. }

         (lambda (n u)
                 (cond ((null u) nil)
                       ((or (eq n (caar u)) (eq n (caddar u)))
                        (retriples n (cdr u)))
                       (t (cons (car u) (retriples n (cdr u))))))
------------------------------------------------------------------------------------
add-triple
   { Updates the global UNIVERSE-EDGE-LIST to reflect the new
     edge given by the triple (N1 E N2). E points from N1 to N2. }

         (lambda (n1 e n2)
                 (setq universe-edge-list (append universe-edge-list
                                                  (list
                                                   (list n1 e n2)))))
------------------------------------------------------------------------------------
```

Text continued from page 396:

Cromemco and (T.(L.C)) LISP is more complex, more powerful, and more baroque. Particularly useful is the ability to specify an arbitrary number of local variables, how each is to be initialized, and how each is to be modified at each iteration. Also, one can specify an arbitrary number of exit tests and associated exit values. Finally, an arbitrary and possibly empty sequence of expressions make up the loop body. Our counting example above for Cromemco and (T.(L.C)) LISP is given in listing 2b.

Nonstructured Function Exits

Sometimes we want a function to exit from an arbitrary number of function call levels. For example, we might design a system that always allows users to type QUIT to return to the system's top command level. The CATCH and THROW forms of Cromemco and (T.(L.C)) LISP give this capability.

For example:

(CATCH *label expression-list*)

says to evaluate the *expression-list*, much like a PROGN. If, during that evaluation, the expression:

(THROW *label exit-expression-list*)

is evaluated, then the CATCH immediately returns with the value returned by treating *exit-expression-list* as a PROGN. This exit ignores any intervening computation or pending functions specified within the CATCH *expression-list*. If a THROW with the corresponding label is not evaluated, the CATCH is treated just like a PROGN. Note that the label is just an atom to establish a correspondence between a given CATCH and THROW.

Input and Output in LISP

Since LISP is a highly interactive language, an implementation must have high-quality I/O (input/output) capabilities. A user will be involved with three similar (and often interchangeable) aspects of I/O. First,

there is the common method of interaction with the interpreter: typing expressions and reading the results. Second, there are the techniques of saving and restoring disk files containing programs and data. Third, there are the input and output operations that happen during user-function execution.

The distinctions here are somewhat arbitrary. Since the difference between program and data is explicitly not enforced in LISP, it is easy to create functions that, for instance, write themselves onto disk. In fact, a common way to load programs is to redefine the source of expressions for the "driver" as a disk file rather than the keyboard. For the sake of clarity, though, we discuss the three aspects of I/O mentioned above as separate topics.

Terminal I/O in all three LISPs leaves something to be desired. muLISP allows for CP/M-style within-the-line editing during input. It recognizes ↑X (control-X) as rubout; ↑R as *retype line*; ↑U as *abort line*. It has the usual backspace and delete characters. If the user, while typing an expression, goes beyond one line of text, the system does not reprompt the user. This is especially important if the user is not sure if the form he or she is typing is correct (in terms of matching parentheses). The user has no indication from the system that it is expecting more input rather than executing the desired expression.

Cromemco and (T.(L.C)) LISP accept input in an immediate mode. When appropriate, they do not wait for a carriage return to accept a legal expression. Unfortunately, they allow no within-the-line editing except for backspacing. On a hard-copy terminal, this can be extremely frustrating. On a video terminal, this would not be a serious problem.

Cromemco and (T.(L.C)) LISP have very flexible and easy-to-use read-macro capabilities. The input routines are table-driven in such a way that the user can easily redefine the meaning of *any* ASCII (American Standard Code for Information Interchange) character, even to the point of causing the system to invoke a

Text continued on page 407

Listing 5: *A set of LISP expressions used to conduct the benchmarks of table 2.*

```
% Expressions to set up the basic benchmarks %


(SETQ LC (BUILD-LONG-CONS 50 'A))

(SETQ DC (BUILD-DEEP-CONS 50 'A))

(SETQ LONG (EVAL LC))

(SETQ DEEP (EVAL DC))

(SETQ BIGCAR (NESTED-APPLICATION 'CAR 49 'DEEP))

(SETQ BIGCDR (NESTED-APPLICATION 'CDR 49 'LONG))

(SETQ LONG1 (APPEND LONG '(B)))

(DE MIX-4-1 (LENGTH E1 E2)
 (COND
      ((LT LENGTH 1) NIL)
      (T ( APPEND (LIST E1 E1 E1 E1 E2)
                  (MIX-4-1 (SUB LENGTH 5) E1 E2)
         )
     )))

(SETQ LONG41 (MIX-4-1 50 'A 'B))

% The muLISP version of tester  %

(DE TESTER (FORM)
 (SETQ COUNT 0)          % initialize the count %
 (PRINT (RECLAIM))       % perform an initial garbage collect %
 (LOOP            % loop infinitly (until an external "interrupt") %
      (EVAL FORM)      % eval the expression to be tested %
      (SETQ COUNT (PLUS COUNT 1)) % increment the count %
 ))
```

Listing 5 continued on page 406

Listing 5 continued:

```
% The next four definitions are helpers to enter the data %
% base.  DF is the Cromemco and (T.(L.C)) LISP function   %
% to define call-by name, no-spread functions. DE defines %
% a call-by-value spread function.                        %

(DF F (X) (FIRST-BORN (CAR X) (CADR X)))

(DF B (X) (BORN (CAR X) (CADR X) (CADDR X) (CADDDR X)))

(DF M (X) (MARRIED (CAR X) (CADR X)))

(DF C (X) (C-1 (CAR X) (CADR X) (CDDR X)))

(DE C-1 (P1 P2 CS-LIST)
(COND ((NULL CS-LIST) NIL)
(T (CONS (BORN (CAR CS-LIST) P1 P2 (CADR CS-LIST))
         (C-1 P1 P2 (CDDR CS-LIST))))))



% The following expressions enter the BAGGINS and        %
% TOOK family trees.                                     %


(MARRIED (F BALBO-B MALE) (F BERYLLA-BOFFIN FEMALE) )

(C BALBO-B BERYLLA-BOFFIN MUNGO-B MALE PANSY-B FEMALE PONTO-B MALE
                          LARGO-B MALE LILY-B FEMALE)

(MARRIED (F LAURA-GRUBB FEMALE) (QUOTE MUNGO-B))

(C LAURA-GRUBB MUNGO-B BUNGO-B MALE)

(MARRIED (F BELLADONNA-TOOK FEMALE) (QUOTE BUNGO-B))

(C BELLADONNA-TOOK BUNGO-B BILBO-B MALE)

(MARRIED (F TANTA-HORNBLOWER FEMALE) (QUOTE LARGO-B))

(C TANTA-HORNBLOWER LARGO-B FOSCO-B MALE)

(MARRIED (F RUBY-BOLGER FEMALE) (QUOTE FOSCO-B))

(C RUBY-BOLGER FOSCO-B DROGO-B MALE)

(MARRIED (F PRIMULA-BRANDYBUCK FEMALE) (QUOTE DROGO-B))

(C PRIMULA-BRANDYBUCK DROGO-B FRODO-B MALE)

(MARRIED (F THE-OLD-TOOK MALE) (F ADAMANTA-CHUBB FEMALE))

(C THE-OLD-TOOK ADAMANTA-CHUBB BELLADONNA-TOOK FEMALE MIRABELLA-TOOK FEMALE)

(MARRIED (QUOTE MIRABELLA-TOOK) (F GORBADOC-BRANDYBUCK MALE))

(C MIRABELLA-TOOK GORBADOC-BRANDYBUCK PRIMULA-BRANDYBUCK FEMALE)

A.
```

Text continued from page 405:
MACRO form when it sees a given character.

Although it is possible to redefine the READ function in muLISP, it is not as convenient as the read-macro capability described above. An example of the usefulness of read-macros is:

'expression

which, in (T.(L.C)) and Cromemco LISP, will be transformed into:

(QUOTE *expression*)

Not only is this not done for you in muLISP, it is not easy to change the system to do it.

To overcome the lack of a read-macro capability, muLISP provides auto-quoting. This means that any atom not bound to a value is bound to itself as a value. This is normally done for numbers (the value of " 3" is three), but most LISP systems raise an error when asked for the value of an undefined atom. The consequences of this are discussed further in the section on error handling.

Disk I/O

Basically, programs are stored on disk as text files or "internal image" files. Text files here are simply ASCII files of function definitions, atom values, and function calls in the same "free-format" style used when typing at the console. Internal image files are "snapshots" of the memory taken at the time they were created, including all the bindings of values that were in effect. muLISP compresses all active data structures that define the environment and generates a coded file that can be loaded with the execution system. The other two LISPs take advantage of the SAVE utility of CP/M and CDOS. They exit to the operating system, and the user must explicitly SAVE a memory image of the entire user area.

In muLISP, the internal image files can also be brought in, using LISP functions. Restoring an environment in this way is fast, but it will explicitly destroy any environment (bindings) that were in effect at the time of the load. In the other LISPs, one is actually reloading memory with the exact contents it had at the time of the exit. This, again, is done through CP/M or CDOS and cannot be done from LISP.

On the other hand, (T.L.C)) LISP and Cromemco LISP both have an auto-load feature not available in muLISP. This feature, while complicated to use, allows the programmer to store functions on disk as part of a large virtual memory. Functions can be stored and loaded only if actually needed (called). After the execution of the function, the system can reclaim the space it occupied (NOKEEP or SMASH), or the function can remain resident (KEEP or NOSMASH) after its first access.

Program-controlled I/O in all three LISPs is surprisingly easy, partly because the LISP language allows the programmer to treat programs as data. Still, "CP/M-compatible" disk I/O is generally a messy subject at best, and all three of these LISPs do an exceptional job of hiding the gory details from the programmer.

Space Management

Since data structures in LISP are dynamic (ie: their size changes during program execution), it is generally a good idea to have dynamic reallocation of memory space in a LISP system. This means that there is no a priori limit on the number of variables, functions, or strings. Rather, as more space is needed for one kind of object, it is found at the expense of space available for other kinds of objects.

Cromemco and (T.(L.C)) LISP accomplish dynamic allocation by a technique in which memory is broken into 256 pages of 256 bytes each. Any of these pages can, in theory, be used for storage of any data type. But the entire page is always used for the same type of object. This scheme has two major advantages. First, it simplifies type checking. The high byte of any object's address defines the type of that object as well as identifying its location. The page-byte-to-type correspondence is kept in a table in memory. This table allows for the second advantage. If more space for a

given type of object is needed, a page of memory is allocated by simply changing the entry in the table for an unused page. If, on the other hand, an allocated page is made free (by the garbage-collection process), a change to the table allows this space to be claimed by another data type.

Unfortunately, the stack, which is used for both variables and control information, must use a contiguous area of memory if it is to be fast. This means that when the stack is full the system cannot allocate an arbitrary free page of memory to the stack. A solution to this would be to move other data around to free up a page adjacent to the stack. But, with the pointer conventions discussed above, this would be a very messy and time-consuming job. Therefore, Cromemco and (T.(L.C)) LISP use a fixed-size stack. This decision poses a real problem because recursive-style and iterative-style programming make very different demands on the size of the stack. In fact, curiously, the stack size is fixed regardless of the total memory size of the system.

muLISP uses a truly dynamic scheme. At any time, all data types are competing for memory. As demands for one type increase, the other spaces shrink. Because this includes the stack, space is better used in this system. The cost of this feature is, of course, time. The user must wait for data areas to be moved around during program execution. However, we found the time penalty to be minimal.

Linking

muLISP and Cromemco LISP both support user-defined assembly-language functions. The current version of (T.(L.C)) LISP apparently does not. Assembly-language routines allow the user to extend his or her LISP system in various ways. Special functions can be made to run significantly faster, or functions can be written to take advantage of special hardware such as a color graphics screen.

The Cromemco LISP system gives the user extensive, if obtuse, documentation and several support programs to allow the user to build assembly-language routines that are linked into the LISP system. Once a linked system is created, it can be saved as an internal image file and then used as the regular LISP system.

The muLISP solution is less ambitious but still workable. muLISP allows up to four assembly-language routines to be incorporated into the system. The routines must be called by jump instructions located in fixed addresses in memory, and the bodies of the routines must exist in locations "invisible" to LISP—that is, above the operating system. Since the routines are not in the LISP area, saving an internal image file of muSTAR will not allow the user to reload the linked system. Rather, the system must be regenerated each time it is used. This could be done in a straightforward way using a CP/M command file.

User Environment

muLISP exhibits an approach to the environment presented by the LISP system that differs from the

other two LISPs. One example of this is the idea of having a separate *development environment* as well as an *execution environment.* A development environment supports editing and debugging of functions (programs) in an interactive setting. While development and testing can be done in muLISP's execution system, there are no facilities to make this easy. Another example of the difference is the related stance on error handling, which is discussed below.

The development subsystem, muSTAR, is an internal image file which is delivered with the muLISP system. (It is an application program written in LISP.) muSTAR is a menu-based program that allows for the user to pick any of the following options:

- Edit Function
- Edit Variable
- Edit Property
- Eval LISP
- Eval-Quote LISP
- Trace Function
- Untrace Function
- Read File
- Write File
- Select Drive

Menu-based systems are generally designed to be used with video terminals. This one is no exception: it is a joy on the screen of a 9600 bps terminal and very frustrating on a 300 bps DECwriter.

The editor that comes with muSTAR is a flexible screen editor intended to be adaptable to any type of video terminal. Unfortunately, the "interrupt execution" character, Escape, is used by some terminals for cursor control. Since Escape is detected at a very low level in the system, there is no way to tailor the screen editor to use these terminals. Unlike some LISP "structure" editors that use atoms and expressions as the units to be modified, the muSTAR editor is a conventional character-oriented screen editor; however, it is convenient and easy to use. When functions are being edited, the text is pretty-printed to make it easier to read and edit.

The Trace and Untrace facilities allow the user to specify to the muSTAR system that when a given function is called the system should print its arguments *before* the execution of the function and the result *afterward*. This is the single most important tool for the user in the process of debugging and developing programs.

Read and Write are for text files and assume a CP/M file extension of ".LIB". The files can be created either by muSTAR or by an external editor. Read works in the obvious way. Write, however, writes out only functions and variables whose names appear on the property list of the atom that is the name of the file. While this can be done using the Edit Property function of muSTAR, it is easy to forget to add new function names during a session and thus lose your work when you exit the muSTAR system.

The error-handling facility in muLISP is virtually nonexistent. The three "advisory" messages: ZERO DIVIDE ERROR, END-OF-FILE READ, and NO DISK SPACE are printed at the console, and the

offending primitive function is forced to return NIL. Execution of the rest of the user function proceeds, according to the manual, "normally." The only error that causes termination of execution is INSUFFICIENT MEMORY SPACE. When execution stops, as when the Escape key is typed, the user has four options. He or she can continue execution, go back to the top-level driver, restart muLISP, or go back to the CP/M system. Unfortunately, the user cannot examine the functions or arguments that caused the problem.

Because of the auto-quoting and implicit-sequence-evaluation features of the system, there are no other errors that can occur during program execution. In fact, since evaluation of any syntactically legal expression is defined, and the input routines for the driver loop ensure that only legal expressions are read in, the user cannot cause any error other than the ones listed above.

Although this may be an elegant concept, it makes debugging awkward at best and virtually impossible at worst except for the Trace option available in muSTAR. Since this is not available in the core muLISP system, you would always do development in muSTAR.

Cromemco LISP and (T.(L.C)) LISP take a more traditional attitude to the user environment and error handling. Errors are flagged in many situations. In particular, the errors UNDEFINED VARIABLE and WRONG NUMBER OF ARGUMENTS, as well as data-type violations, are checked for during program evaluation. The characters G, Control-G, and Bell act like the Escape key in muLISP to end execution of user functions. In addition, the function ERROR can be called by a function at any time.

Once an error occurs, evaluation stops, a message is printed, and the user has several options. He or she can examine the function or arguments that caused the error, trace the execution stack back through all the nested calls, or "pop" up the stack (to the top or any intermediate place) giving a return value for the function that was called at that level. Although these functions are a good idea, they are poorly explained in the manual.

Documentation, Library Software

We were very pleased with the quality of the documentation for all three LISPs. Because Cromemco and (T.(L.C)) LISP are just different versions of the same program, the two user's manuals are almost identical. These manuals begin with a long discussion of LISP style and philosophy and include a discussion of how to code a recursive descent parser in LISP. This background information is quite good and will be a great help to a beginner. Most of the function descriptions include an illustrative example. The Cromemco LISP manual adds a section on the internal representation of data structures and gives information needed to link to assembly-language subroutines. The (T.(L.C)) LISP manual includes some annotated LISP examples adapted from *Artificial Intelligence Programming* (see the "Where to Learn LISP" text box for a description of this book and

other useful LISP information). These examples are prefaced by a discussion of the differences between (T.(L.C)) LISP and the LISP used in *Artificial Intelligence Programming*. We found this discussion quite useful. Both manuals are about 135 pages long.

The muLISP manual, which is about 100 pages long, is shorter and terser, but of high quality. This manual gives a limited amount of background information. The function descriptions are in a formal metalanguage that is complete but often obscure. These descriptions would be much clearer if they included examples. The manual includes commented listings of many useful utilities and the muSTAR development environment, and they will be quite useful for users who wish to tailor their LISP environment. In particular, there are instructions for tailoring the muLISP screen editor to different kinds of terminals.

Cromemco LISP is distributed with a fairly complete set of Cromemco software, including the CDOS operating system, several CDOS utilities, and a screen editor. Unfortunately, the screen editor can only be used with a Cromemco terminal. This is downright unfriendly of Cromemco, particularly since it is trivial to provide the "hooks" to do screen editing with almost any modern terminal. Also provided are files with LISP utilities, a trace function, a pretty-printer program, examples from *Artificial Intelligence Programming*, and examples of the more esoteric features of Cromemco LISP.

(T.(L.C)) LISP is distributed with the same example and utility files as Cromemco LISP. Also included are several additional files of examples.

muLISP is distributed with the muSTAR utility and the other utilities described in the manual. Also included are several games and programs, including a version of Weizenbaum's ELIZA, called DOCTOR, and a guessing game which learns, called ANIMAL.

muLISP has the beginnings of an active user group and software library. Information about the user group and the software is published in a small newsletter available to muLISP purchasers. (T.(L.C)) LISP purchasers also receive a newsletter, though it is less formal and less regular. As of now, there is no (T.(L.C)) LISP users' group.

Conclusions

- Cromemco and (T.(L.C)) LISP have many modern features, yet they still run acceptably fast. The auto-load feature potentially allows very large programs to run in a virtual-memory environment. The documentation is quite good and would be useful for LISP beginners. Cromemco LISP also includes information that would be useful to someone adding his or her own machine-language subroutines. A major drawback of these LISPs is a small, fixed-sized stack that severely limits the use of recursive functions. (T.(L.C)) LISP is the cheapest of the LISPs reviewed here—$150. Cromemco LISP, with only a small amount of additional functionality, is the most expensive—$295.
- muLISP is an extremely fast LISP with a complete but basic set of

features. It is distributed with muSTAR, a nice LISP development environment that includes a screen editor. The documentation is good, but it is too terse and formal for beginners. Much of the speed of muLISP comes from features that make programs hard to read and hard to debug. In particular, muLISP does almost no type checking or error detection.

• LISP is alive and well and living in a Z80 microprocessor. Although there are great differences between muLISP and the other two packages, we feel that all three are successful products. Each would allow a user to develop and use fairly large LISP programs. ■

Acknowledgments

The benchmark tests were performed on a system purchased and supported by Army Research Office grant DAAG29-79-G-0046. We would like to thank E Jeffrey Conklin and Caxton C Foster.

Where to learn LISP: Recommended Books and Articles

1. Allen, J. *Anatomy of LISP*. New York: McGraw-Hill Book Co, 1978. An examination of many issues in computer science through LISP-tinted spectacles. This is also the only published discussion of many modern LISP implementation techniques and styles.
2. Allen, J. "An Overview of LISP" in BYTE, August 1979, page 10. A compact overview to LISP style and usage. All the important LISP functions are discussed. The most difficult aspect of learning LISP is understanding exactly when and how values get bound to names. These issues are not discussed.
3. Charniak, Eugene, Christopher Riesback, and Drew McDermott. *Artificial Intelligence Programming*. Hillsdale NJ: Lawrence Erlbaum Associates, 1979. A very complete introduction to sophisticated uses of LISP for AI programming. The first few chapters do a good job of explaining the name-value-binding issues.
4. Friedman, Daniel. *The Little LISPer*. London, England: Science Research Associates Inc, 1974. An entertaining introduction to the style of LISP programming. This book does *not* cover everything you need to know to use LISP on a real machine. It, again, avoids key issues of how and when LISP names get values.
5. McCarthy, John. "Recursive Functions of Symbolic Expressions and Their Computation by Machine," *Communications of the Association for Computing Machinery*, pages 184 through 195, April 1960. This is where it all started, the article that suggested that the mathematical lambda calculus could be embodied in a programming language.
6. Winston, Patrick Henry. *Artificial Intelligence*. Reading MA: Addison-Wesley, 1977. An easily understood introduction to AI and AI programming.
7. Winston, Patrick Henry and Berthold Klaus Horn. *LISP*. Reading MA: Addison-Wesley, 1981. A pleasant, chatty introduction to LISP.

BYTE's Bits

Microsoft Drops APL Interpreter

Microsoft has dropped work on an APL interpreter. The demand of other projects has caused the company to stop work on the interpreter for 8-bit microcomputers. The company still plans to develop a 16-bit version.

BYTE's Bugs

Price Mis-Steak

In the April 1981 "Software Received," the price of the "Beef Cattle Least-Cost Ration Program" was incorrectly listed. The correct price is $495. A demonstration tape of the program is available for $5.

For information on the program, contact Agricultural Software Consultants, 1706 Santa Fe, Kingsville TX 78363 (512) 595-1937. ■

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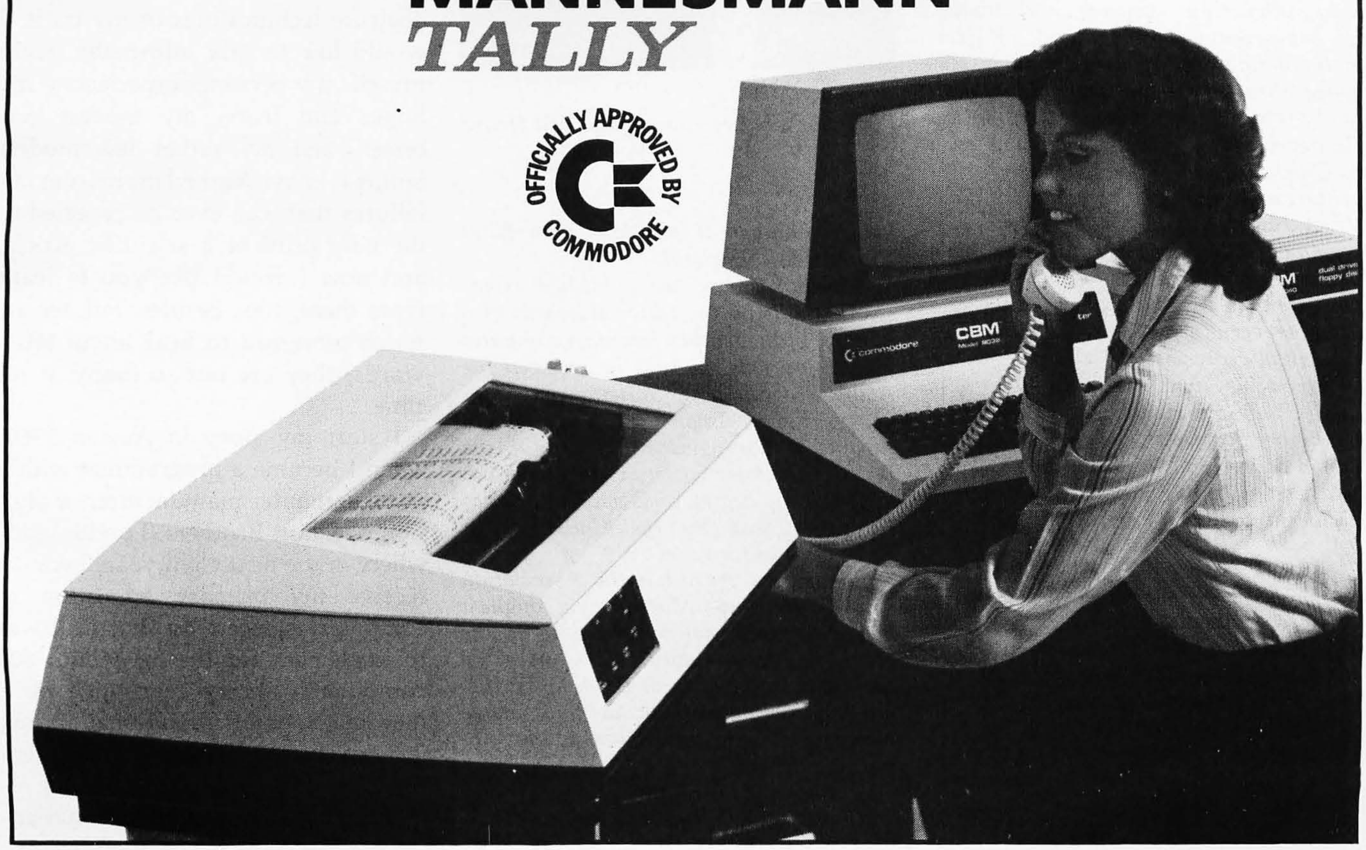
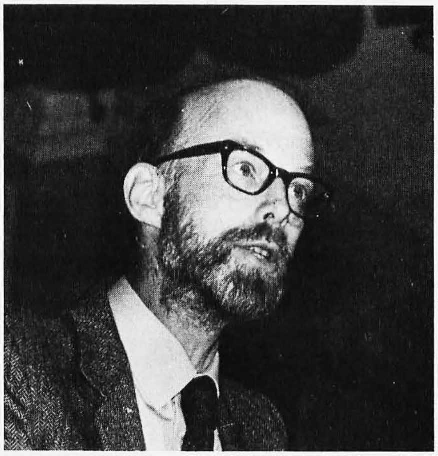


The Emperor's Old Clothes

Charles Antony Richard Hoare
Oxford University, England



Professor Charles Antony Richard Hoare

The 1980 ACM Turing Award was presented to Charles Antony Richard Hoare, Professor of Computation at Oxford University, England, by Walter Carlson, chairman of the awards committee. The presentation took place at the ACM Annual Conference in Nashville, Tennessee, October 27, 1980.

Professor Hoare was selected by the General Technical Achievement Award Committee for his fundamental contributions to the definition and design of programming languages. His work is characterized by an unusual combination of insight, originality, elegance, and impact. He is best known for his work on axiomatic definitions of programming languages through the use of techniques popularly referred to as axiomatic semantics. He developed ingenious algorithms such as Quicksort and was responsible for inventing and promulgating advanced data-structuring techniques in scientific programming languages. He has also made important contributions to operating systems through the study of monitors, and his most recent work is on communicating sequential processes.

Before his appointment to Oxford in 1977, Professor Hoare was Professor of Computer Science at The Queen's University in Belfast, Ireland, from 1968 to 1977, and was a Visiting Professor at Stanford University in 1973. From 1960 to 1968 he held a number of positions with Elliot Brothers Ltd, England.

Professor Hoare has published extensively and is on the editorial boards of a number of the world's foremost computer science journals. In 1973 he received the ACM Programming Systems and Languages Paper Award. Professor Hoare became a Distinguished Fellow of the British Computer Society in 1978 and was awarded the degree of Doctor of Science Honoris Causa *by the University of Southern California in 1979.*

The Turing Award is the Association for Computing Machinery's highest award for technical contributions to the computing community. It is presented each year in memory of Dr A M Turing, an English mathematician who made many important contributions to the computing sciences.

A transcript of Professor Hoare's 1980 Turing Award Lecture follows.

Acknowledgments

BYTE *wishes to thank Professor CAR Hoare and the Association for Computing Machinery for granting us permission to reprint this article, which originally appeared in the February 1981* Communications of the ACM. *Copyright 1981 by the Association for Computing Machinery, Inc. Reprinted by permission.*

My first and most pleasant duty in this lecture is to express my profound gratitude to the Association for Computing Machinery for the great honor which they have bestowed on me and for this opportunity to address you on a topic of my choice. What a difficult choice it is! My scientific achievements, so amply recognized by this award, have already been amply described in the scientific literature. Instead of repeating the abstruse technicalities of my trade, I would like to talk informally about myself, my personal experiences, my hopes and fears, my modest successes, and my rather less modest failures. I have learned more from my failures than can ever be revealed in the cold print of a scientific article, and now I would like you to learn from them, too. Besides, failures are much more fun to hear about afterwards; they are not so funny at the time.

I start my story in August 1960, when I became a programmer with a small computer manufacturer, a division of Elliott Brothers (London) Ltd, where in the next eight years I was to receive my primary education in computer science. My first task was to implement for the new Elliot 803 computer a library subroutine for a new fast method of internal sorting just invented by Shell. I greatly enjoyed the challenge of maximizing efficiency in the simple decimal-ad-

dressed machine code of those days. My boss and tutor, Pat Shackleton, was very pleased with my completed program. I then said timidly that I thought I had invented a sorting method that would usually run faster than SHELLSORT, without taking much extra store. He bet me sixpence that I had not. Although my method was very difficult to explain, he finally agreed that I had won my bet.

I wrote several other tightly coded library subroutines, but after six months I was given a much more important task—that of designing a new advanced high-level programming language for the company's next computer, the Elliott 503, which was to have the same instruction code as the existing 803 but run sixty times faster. In spite of my education in classical languages, this was a task for which I was even less qualified than those who undertake it today. By great good fortune there came into my hands a copy of the Report on the International Algorithmic Language ALGOL 60. Of course, this language was obviously too complicated for our customers. How could they ever understand all those begins and ends when even our salesmen couldn't?

Around Easter 1961, a course on ALGOL 60 was offered in Brighton, England, with Peter Naur, Edsger W Dijkstra, and Peter Landin as tutors. I attended this course with my colleague in the language project, Jill Pym, our divisional Technical Manager, Roger Cook, and our Sales Manager, Paul King. It was there that I first learned about recursive procedures and saw how to program the sorting method which I had earlier found such difficulty in explaining. It was there that I wrote the procedure, immodestly named Quicksort, on which my career as a computer scientist is founded. Due credit must be paid to the genius of the designers of ALGOL 60 who included recursion in their language and enabled me to describe my invention so elegantly to the world. I have regarded it as the

highest goal of programming language design to enable good ideas to be elegantly expressed.

After the ALGOL course in Brighton, Roger Cook was driving me and my colleagues back to London when he suddenly asked, "Instead of designing a new language, why don't we just implement ALGOL 60?" We all instantly agreed—in retrospect, a very lucky decision for me. But we knew we did not have the skill or experience at that time to implement the whole language, so I was commissioned to design a modest subset. In that design I adopted certain basic principles which I believe to be as valid today as they were then.

Principles of Design

The first principle was *security*, the principle that every syntactically incorrect program should be rejected by the compiler and that every syntactically correct program should give a result or an error message that was predictable and comprehensible in terms of the source language program itself. Thus no core dumps should ever be necessary. It was logically impossible for any source language program to cause the computer to run wild, either at compile time or at run time. A consequence of this principle is that every occurrence of every subscript of every subscripted variable was on every occasion checked at run time against both the upper and the lower declared bounds of the array. Many years later we asked our customers whether they wished us to provide an option to switch off these checks in the interests of efficiency on production runs. Unanimously, they urged us not to—they already knew how frequently subscript errors occur on production runs where failure to detect them could be disastrous. I note with fear and horror that even in 1980, language designers and users have not learned this lesson. In any respectable branch of engineering, failure to observe such elementary precautions would have long been against the law.

The second principle in the design of the implementation was *brevity of the object code produced by the compiler and compactness of run time working data*. There was a clear reason for this: the size of main storage on any computer is limited, and its extension involves delay and expense. A program exceeding the limit, even by one word, is impossible to run, especially since many of our customers did not intend to purchase backing stores.

This principle of compactness of object code is even more valid today, when processors are trivially cheap in comparison with the amounts of main store they can address, and backing stores are comparatively even more expensive and slower by many orders of magnitude. If as a result of care taken in implementation the available hardware remains more powerful than may seem necessary for a particular application, the applications programmer can nearly always take advantage of the extra capacity to increase the quality of his program, its simplicity, its ruggedness, and its reliability.

The third principle of our design was that *the entry and exit conventions for procedures and functions should be as compact and efficient as for tightly coded machine-code subroutines*. I reasoned that procedures are one of the most powerful features of a high-level language, in that they

both simplify the programming task and shorten the object code. Thus there must be no impediment to their frequent use.

The fourth principle was that *the compiler should use only a single pass*. The compiler was structured as a collection of mutually recursive procedures, each capable of analyzing and translating a major syntactic unit of the language—a statement, an expression, a declaration, and so on. It was designed and documented in ALGOL 60, and then coded into decimal machine code using an explicit stack for recursion. Without the ALGOL 60 concept of recursion, at that time highly controversial, we could not have written this compiler at all.

I can still recommend single-pass, top-down recursive descent both as an implementation method and as a design principle for a programming language. First, we certainly want programs to be read by *people*, and people prefer to read things once in a single pass. Second, for the user of a time-sharing or personal computer system, the interval between typing in a program (or amendment) and starting to run that program is wholly unproductive. It can be minimized by the high speed of a single-pass compiler. Finally, to structure a compiler according to the syntax of its input language makes a great contribution to ensuring its correctness. Unless we have absolute confidence in this, we can never have confidence in the results of any of our programs.

Principles at Work

To observe these four principles, I selected a rather small subset of ALGOL 60. As the design and implementation progressed, I gradually discovered methods of relaxing the restrictions without compromising any of the principles. So in the end we were able to implement nearly the full power of the whole language, including even recursion, although several features were removed and others were restricted.

In the middle of 1963, primarily as a result of the work of Jill Pym and Jeff Hillmore, the first version of our compiler was delivered. After a few months we began to wonder whether anyone was using the language or taking any notice of our occasional reissue, incorporating improved operating methods. Only when a customer had a complaint did he contact us, and many of them had no complaints. Our customers have now moved on to more modern computers and more fashionable languages, but many have told me of their fond memories of the Elliott ALGOL System. The fondness is not due just to nostalgia, but to the efficiency, reliability, and convenience of that early simple ALGOL System.

As a result of this work on ALGOL, in August 1962 I was invited to serve on the new Working Group 2.1 of the International Federation of Information Processors (IFIP) charged with responsibility for maintenance and development of ALGOL. The group's first main task was to design a subset of the language which would remove some of its less successful features. Even in those days and even with such a simple language, we recognized that a subset could be an improvement on the original. I greatly welcomed the chance of meeting and hearing the wisdom of many of the original language designers. I was astonished and dismayed at the heat and even rancor of their discussions. Apparently the original design of ALGOL 60 had not proceeded in that spirit of dispassionate search for truth which the quality of the language had led me to suppose.

In order to provide relief from the tedious and argumentative task of designing a subset, the working group allocated one afternoon to discussing the features that should be incorporated in the next design of the language. Each member was invited to suggest the improvement he considered most important. On October 11, 1963, my suggestion was to pass on a request of our customers to relax the ALGOL 60 rule of compulsory declaration of variable names and adopt some reasonable default convention such as that of FORTRAN. I was astonished by the polite but firm rejection of this seemingly innocent suggestion. It was pointed out that the redundancy of ALGOL 60 was the

best protection against programming and coding errors which could be extremely expensive to detect in a running program and even more expensive not to. The story of the Mariner space rocket to Venus, lost because of the lack of compulsory declarations in FORTRAN, was not to be published until later. I was eventually persuaded of the need to design programming notations so as to maximize the number of errors which cannot be made, or if made, can be reliably detected at compile time. Perhaps this would make the text of programs longer. Never mind! Wouldn't you be delighted if your Fairy Godmother offered to wave her wand over your program to remove all its errors and only made the condition that you should write out and key in your whole program three times? The way to shorten programs is to use procedures, not to omit vital declarative information.

Among the other proposals for the development of a new ALGOL was that the Switch declaration of ALGOL 60 should be replaced by a more general feature, namely an array of label-valued variables, and that a program should be able to change the values of these variables by assignment. I was very much opposed to this idea, similar to the assigned Go To of FORTRAN, because I had found a surprising number of tricky problems in the implementation of even the simple labels and switches of ALGOL 60. I could see even more problems in the new feature, including that of jumping back into a block after it had been exited. I was also beginning to suspect that programs that used a lot of labels were more difficult to understand and get correct, and that programs that assigned new values to label variables would be even more difficult still.

It occurred to me that the appropriate notation to replace the ALGOL 60 switch should be based on that of the conditional expression of ALGOL 60, which selects between two alternative actions according to the value of a Boolean expression. So I suggested the notation for a "case expression" which selects between any number of alternatives according to the value of an integer expression. That was my second language design proposal. I am still most proud of it, because it raises essentially no problems either for the implementer, the programmer, or the reader of a program. Now, after more than fifteen years, there is the prospect of international standardization of a language incorporating this notation—a remarkably *short* interval compared with other branches of engineering.

Back again to my work at Elliott. After the unexpected success of our ALGOL Compiler, our thoughts turned to a more ambitious project: to provide a range of operating system software for larger configurations of the 503 computer, with card readers, line printers, magnetic tapes, and even a core backing store which was twice as cheap and twice as large as the main store, but fifteen times slower. This was to be known as the Elliott 503 Mark II software system. It comprised:

1. An assembler for a symbolic assembly language in which all the rest of the software was to be written.

2. A scheme for automatic ad-

ministration of code and data overlays, either from magnetic tape or from core backing store. This was to be used by the rest of the software.

3. A scheme for automatic buffering of all input and output on any available peripheral device, again to be used by all the other software.

4. A filing system on magnetic tape with facilities for editing and job control.

5. A completely new implementation of ALGOL 60, which removed all the nonstandard restrictions which we had imposed on our first implementation.

6. A compiler for FORTRAN as it was then.

Deadline Pressures

I wrote documents which described the relevant concepts and facilities, and we sent them to existing and prospective customers. Work started with a team of fifteen programmers, and the deadline for delivery was set some eighteen months ahead, in March 1965. After initiating the design of the Mark II software, I was suddenly promoted to the dizzying rank of Assistant Chief Engineer, responsible for advanced development and design of the company's products, both hardware and software.

Although I was still managerially responsible for the 503 Mark II software, I gave it less attention than the company's new products and almost failed to notice when the deadline for its delivery passed without event. The programmers revised their implementation schedules, and a new delivery date was set some three months ahead, in June 1965. Needless to say, that day also passed without event. By this time, our customers were getting angry and my managers instructed me to take personal charge of the project. I asked the senior programmers once again to draw up revised schedules, which again showed that the software could be delivered within another three months. I desperately wanted to believe it, but I just could not. I disregarded the schedules and began to dig more deeply into the project.

It turned out that we had failed to make any overall plans for the allocation of our most limited resource—main storage. Each programmer expected this to be done automatically, either by the symbolic assembler or by the automatic overlay scheme. Even worse, we had failed to simply count the space used by our own software which was already filling the main store of the computer, leaving no space for our customers to run *their* programs. Hardware address length limitations prohibited adding more main storage.

Clearly, the original specifications of the software could not be met and had to be drastically curtailed. Experienced programmers and even managers were called back from other projects. We decided to concentrate first on delivery of the new compiler for ALGOL 60, which careful calculation showed would take another four months. I impressed upon all the programmers involved that this was no longer just a prediction; it was a promise. If they found they were not meeting their promise, it was their personal responsibility to find ways and means of making good.

The programmers responded magnificently to the challenge. They worked nights and days to ensure completion of all those items of software which were needed by the ALGOL compiler. To our delight, they met the scheduled delivery date; it was the first major item of working software produced by the company over a period of two years.

Our delight was short-lived; the compiler could not be delivered. Its speed of compilation was only two characters per second, which compared unfavorably with the existing version of the compiler operating at about a thousand characters per second. We soon identified the cause of the problem: it was thrashing between the main store and the extension core backing store which was fifteen times slower. It was easy to make some simple improvements, and within a week we had doubled the speed of compilation to four characters per second. In the next two weeks of investigation and reprogramming, the speed was doubled again to eight characters per second. We could see ways in which within a month this could be still further improved, but the amount of reprogramming required was increasing and its effectiveness was decreasing; there was an awful long way to go. The alternative of increasing the size of the main store so frequently adopted in later failures of this kind was prohibited by hardware addressing limitations.

There was no escape: the entire Elliott 503 Mark II software project had to be abandoned, and with it, over thirty man-years of programming effort, equivalent to nearly one man's active working life. And I was responsible, both as designer and as manager, for wasting it.

A meeting of all our 503 customers was called and Roger Cook, who was then manager of the computing division, explained to them that not a single word of the long-promised software would ever be delivered to them. He adopted a very quiet tone of delivery, which ensured that none of the customers could interrupt, murmur in the background, or even shuffle in their seats. I admired but could not share his calm. Over lunch our customers were kind to try to comfort me. They had realized long ago that software to the original specifications could never have been delivered, and even if it had been, they would not have known how to use its sophisticated features, and anyway many such large projects get cancelled before delivery. In retrospect, I believe our customers were fortunate that hardware limitations had protected them from the arbitrary excesses of our software designs. In the present day, users of microprocessors benefit from a similar protection—but not for much longer.

At that time I was reading the early documents describing the concepts and features of the newly announced OS 360, and of a new time-sharing project called Multics. These were far more comprehensive, elaborate, and sophisticated than anything I had imagined, even in the first version of the 503 Mark II software. Clearly IBM and MIT must be possessed of some secret of successful software de-

sign and implementation whose nature I could not even begin to guess at. It was only later that they realized they could not either.

So I still could not see how I had brought such a great misfortune upon my company. At the time I was convinced that my managers were planning to dismiss me. But no, they were intending a far more severe punishment. "OK, Tony," they said. "You got us into this mess, and now you're going to get us out."

"I don't know how," I protested, but their reply was simple. "Well then, you'll have to find out." They even expressed confidence that I could do so. I did not share their confidence. I was tempted to resign. It was the luckiest of all my lucky escapes that I did not.

Of course, the company did everything they could to help me. They took away my responsibility for hardware design and reduced the size of my programming teams. Each of my managers explained carefully his own theory of what had gone wrong, and all the theories were different. At last, there breezed into my office the most senior manager of all, a general manager of our parent company, Andrew St. Johnston. I was surprised that he had even heard of me. "You know what went wrong?" he shouted (he always shouted). "You let your programmers do things which you yourself do not understand." I stared in astonishment. He was obviously out of touch with present-day realities. How could one person ever understand the whole of a modern software product like the Elliott 503 Mark II software system?

I realized later that he was absolutely right; he had diagnosed the true cause of the problem and he had planted the seed of its later solution.

Defining the Problems

I still had a team of some forty programmers. We needed to retain the goodwill of customers of our new machine and even regain the confidence of the customers for our old one. But what should we actually plan to do when we knew only one thing—that all our previous plans had failed? I therefore called an all-day meeting of our senior programmers on October 22, 1965, to thrash out the question among us. I still have the notes of that meeting. We first listed the recent major grievances of our customers: cancellation of products, failure to meet deadlines, excessive size of software "not justified by the usefulness of the facilities provided," excessively slow programs, failure to take account of customer feedback. "Earlier attention paid to quite minor requests of our customers might have paid as great dividends of goodwill as the success of our most ambitious plans," we concluded.

We then listed our own grievances: lack of machine time for program testing, unpredictability of machine time, lack of suitable peripheral equipment, unreliability of the hardware even when available, dispersion of programming staff, lack of equipment for keypunching of programs, lack of firm hardware delivery dates, lack of technical writing effort for documentation, lack of software knowledge outside the programming group, interference from higher managers who imposed decisions without a full realization of the more intricate implications of the matter, and overoptimism in the face of pressure from customers and the sales department.

But we did not seek to excuse our failure by these grievances. For example, we admitted that it was the duty of programmers to educate their managers and other departments of the company by presenting the necessary information in a simple palatable form. The hope "that deficiencies in original program specifications could be made up by the skill of a technical writing department...was misguided. The design of a program and the design of its specification must be undertaken in parallel by the same person, and they must interact with each other. A lack of clarity in specification is one of the surest signs of a deficiency in the program it describes, and the two faults must be removed simultaneously before the project is embarked upon." I wish I had followed this advice in 1963; I wish we all would follow it today.

My notes of the proceedings of that day in October 1965 include a complete section devoted to failings within the software group; this section rivals the most abject self-abasement of a revisionist official in the Chinese cultural revolution. Our main failure was overambition. "The goals which we have attempted have obviously proved to be far beyond our grasp." There was also failure in prediction, in estimation of program size and speed, of effort required, in planning the coordination and interaction of programs, in providing an early warning that things were going wrong. There were faults in our control of program changes, documentation, liaison with other departments, with our management, and with our customers. We failed in giving clear and stable definitions of the responsibilities of individual programmers and project leaders. Oh, need I go on? What was amazing was that a large team of highly intelligent programmers could labor so hard and so long on such an unpromising project. You know, you shouldn't trust us intelligent programmers. We can think up such good arguments for convincing ourselves and each other of the utterly absurd. Especially don't believe us when we promise to repeat an earlier success, only bigger and better next time.

The last section of our inquiry into the failure dealt with the criteria of quality of software. "In the recent struggle to deliver any software at all, the first casualty has been consideration of the quality of the software delivered. The quality of software is measured by a number of totally incompatible criteria, which must be carefully balanced in the design and implementation of every program." We then made a list of no less than seventeen criteria which has been published in a guest editorial in Volume 2 of the journal *Software Practice and Experience*.

Recovery Period

How did we recover from the catastrophe? First, we classified our 503 customers into groups, according to the nature and the size of the hard-

ware configurations which they had bought. For example, those with magnetic tapes were all in one group. We assigned to each group of customers a small team of programmers and told the team leader to visit the customers to find out what they wanted, to select the easiest request to fulfill, and to make plans (but not promises) to implement it. In no case would we consider a request for a feature that would take more than three months to implement and deliver. The project leader would then have to convince *me* that the customer's request was reasonable, that the design of the new feature was appropriate, and that the plans and schedules for implementation were realistic. Above all, I did not allow anything to be done which I did not myself understand. It worked! The software requested began to be delivered on the promised dates. With an increase in our confidence and that of our customers, we were able to undertake fulfilling slightly more ambitious requests. Within a year, we had recovered from the disaster. Within two years, we even had some moderately satisfied customers.

Thus we muddled through by common sense and compromise to something aproaching success. But I was not satisfied. I did not see why the design and implementation of an operating system should be so much more difficult than that of a compiler. This is the reason why I have devoted my later research to problems of parallel programming and language constructs which would assist in clear structuring of operating systems—constructs such as monitors and communicating processes.

While I was working at Elliott, I became very interested in techniques for formal definition of programming languages. At that time, Peter Landin and Christopher Strachey proposed to define a programming language in a simple functional notation that specified the effect of each command on a mathematically defined abstract machine. I was not happy with this proposal because I felt that such a definition must incorporate a number of fairly arbitrary representation decisions and would not be much simpler in principle than an implementation of the language for a real machine. As an alternative, I proposed that a programming language definition should be formalized as a set of axioms, describing the desired properties of programs written in the language. I felt that carefully formulated axioms would leave an implementation the necessary freedom to implement the language efficiently on different machines and enable the programmer to prove the correctness of his programs.

But I did not see how to actually do it. I thought that it would need lengthy research to develop and apply the necessary techniques, and that a university would be a better place to conduct such research than industry. So I applied for a chair in Computer Science at the Queen's University of Belfast, where I was to spend nine happy and productive years. In October 1968, as I unpacked my papers in my new home in Belfast, I came across an obscure reprint of an article by Bob Floyd entitled, "Assigning Meanings to Programs." What a stroke of luck! At last I could see a way to achieve my hopes for my research. Thus I wrote my first paper on the axiomatic approach to computer programming, published in the *Communications of the ACM* in October 1969.

Just recently, I have discovered that an early advocate of the assertional method of program proving was none other than Alan Turing himself. On June 24, 1950, at a conference in Cambridge, he gave a short talk entitled, "Checking a Large Routine," which explains the idea with great clarity. "How can one check a large routine in the sense of making sure that it's right?" Turing asked. "In order that the man who checks may not have too difficult a task, the programmer should make a number of definite *assertions* which can be checked individually, and from which the correctness of the whole program easily follows."

Consider the analogy of checking

an addition. If the sum is given as a column of figures with the answer below, one must check the whole at one sitting. But if the totals for the various columns are given with the carries added in separately, the checker's work is much easier, being split up into the checking of the various assertions (that each column is correctly added) and the small addition (of the carries to the total). This principle can be applied to the checking of a large routine, but we will illustrate the method by means of a small routine: one to obtain *n* factorial without the use of a multiplier. Unfortunately, there is no coding system sufficiently generally known to justify giving this routine in full, but a flow diagram will be sufficient for illustration. That brings me back to the main theme of my talk, the design of programming languages.

During the period August 1962 to October 1966, I attended every meeting of the IFIP ALGOL working group. After completing our labors on the IFIP ALGOL subset, we started on the design of ALGOL X, the intended successor to ALGOL 60. More suggestions for new features were made and in May 1965, Niklaus Wirth was commissioned to collate them into a single language design. I was delighted by his draft design, which avoided all the known defects of ALGOL 60 and included several new features, all of which could be simply and efficiently implemented, and safely and conveniently used.

The description of the language was not yet complete. I worked hard on making suggestions for its improvement, and so did many other members of our group. By the time of the next meeting in St. Pierre de Chartreuse, France, in October 1965, we had a draft of an excellent and realistic language design which was published in June 1966 as "A Contribution to the Development of ALGOL" in *Communications of the ACM*. It was implemented on the IBM 360 and given the title ALGOL W by its many happy users. It was not only a worthy successor of ALGOL 60, it was even a worthy predecessor of Pascal.

At the same meeting, the ALGOL committee had placed before it a short, incomplete and rather incomprehensible document describing a different, more ambitious and, to me, a far less attractive language. I was astonished when the working group, consisting of all the best known international experts of programming languages, resolved to lay aside the commissioned draft on which we had all been working and swallow a line with such an unattractive bait.

Two Design Paths

This happened just one week after our inquest on the 503 Mark II software project. I gave desperate warnings against the obscurity, the complexity, and overambition of the new design, but my warnings went unheeded. I conclude that there are two ways of constructing a software design: One way is to make it so simple that there are *obviously* no deficiencies, and the other way is to make it so complicated that there are no *obvious* deficiencies.

The first method is far more difficult. It demands the same skill, devotion, insight, and even inspiration as the discovery of the simple physical laws which underlie the complex phenomena of nature. It also requires a willingness to accept objectives which are limited by physical, logical, and technological constraints, and to accept a compromise when conflicting objectives cannot be met. No committee will ever do this until it is too late.

So it was with the ALGOL committee. Clearly the draft which it preferred was not yet perfect. So a new and final draft of the new ALGOL language design was promised in three months' time; it was to be submitted to the scrutiny of a subgroup of four members including myself. Three months came and went, without a word of the new draft. After six months, the subgroup met in the Netherlands. We had before us a longer and thicker document, full of errors corrected at the last minute, describing yet another but to me, equally unattractive language. Niklaus Wirth and I spent some time trying to get removed some of the deficiencies in the design and in the description, but in vain. The completed final draft of the language was promised for the next meeting of the full ALGOL committee in three months' time.

Three months came and went—not a word of the new draft appeared. After six months, in October 1966,

the ALGOL working group met in Warsaw. It had before it an even longer and thicker document, full of errors corrected at the last minute, describing equally obscurely yet another different, and to me, equally unattractive language. The experts in the group could not see the defects of the design and they firmly resolved to adopt the draft, believing it would be completed in three months. In vain, I told them it would not. In vain, I urged them to remove some of the technical mistakes of the language, the predominance of references, the default type conversions. Far from wishing to simplify the language, the working group actually asked the authors to include even more complex features like overloading of operators and concurrency.

When any new language design project is nearing completion, there is always a mad rush to get new features added before standardization. The rush is mad indeed, because it leads into a trap from which there is no escape. A feature which is omitted can always be added later, when its design and its implications are well understood. A feature which is included before it is fully understood can never be removed later.

At last, in December 1968, in a mood of black depression, I attended the meeting in Munich at which our long-gestated monster was to come to birth and receive the name ALGOL 68. By this time, a number of other members of the group had become disillusioned, but too late: the committee was now packed with supporters of the language, which was sent up for promulgation by the higher committees of IFIP. The best we could do was to send with it a minority report, stating our considered view that "...as a tool for the *reliable creation* of sophisticated programs, the language is a failure." This report was later suppressed by IFIP, an act which reminds me of the lines of Hilaire Belloc:

> But scientists, who ought to know
> Assure us that it must be so.
> Oh, let us never, never doubt
> What nobody is sure about.

I did not attend any further meetings of that working group. I am pleased to report that the group soon came to realize that there was something wrong with their language and with its description; they labored hard for six more years to produce a revised description of the language. It is a great improvement but I'm afraid that, in my view, it does not remove the basic technical flaws in the design, nor does it begin to address the problem of its overwhelming complexity.

Programmers are always surrounded by complexity; we cannot avoid it. Our applications are complex because we are ambitious to use our computers in ever more sophisticated ways. Programming is complex because of the large number of conflicting objectives for each of our programming projects. If our basic tool, the language in which we design and code our programs, is also complicated, the language itself becomes part of the problem rather than part of its solution.

Another Project

Now let me tell you about yet another overambitious language project. Between 1965 and 1970 I was a member and even chairman of the Technical Committee No. 10 of the European Computer Manufacturers Association. We were charged first with a watching brief and then with the standardization of a language to end all languages, designed to meet the needs of all computer applications, both commercial and scientific, by the greatest computer manufacturer of all time. I had studied with interest and amazement, even a touch of amusement, the four initial documents describing a language called NPL, which appeared between March 1 and November 30, 1964. Each was more ambitious and absurd than the last in its wishful speculations. Then the language began to be implemented and a new series of documents began to appear at six-monthly intervals, each describing the final frozen version of the language, under its final frozen name PL/I.

But to me, each revision of the doc-

ument simply showed how far the initial *F-level* implementation had progressed. Those parts of the language that were not yet implemented were still described in free-flowing flowery prose giving promise of unalloyed delight. In the parts that *had* been implemented, the flowers had withered; they were choked by an undergrowth of explanatory footnotes, placing arbitrary and unpleasant restrictions on the use of each feature and loading upon a programmer the responsibility for controlling the complex and unexpected side-effects and interaction effects with all the other features of the language.

At last, March 11, 1968, the language description was nobly presented to the waiting world as a worthy candidate for standardization. But it was not. It had already undergone some seven thousand corrections and modifications at the hand of its original designers. Another twelve editions were needed before it was finally published as a standard in 1976. I fear that this was not because everybody concerned was satisfied with its design, but because they were thoroughly bored and disillusioned.

For as long as I was involved in this project, I urged that the language be simplified, if necessary by subsetting, so that the professional programmer would be able to understand it and be able to take responsibility for the correctness and cost-effectiveness of his programs. I urged that the dangerous features such as defaults and *on* conditions be removed. I knew that it would be impossible to write a wholly reliable compiler for a language of this complexity, and impossible to write a wholly reliable program when the correctness of each part of the program depends on checking that every other part of the program has avoided all the traps and pitfalls of the language.

At first I hoped that such a technically unsound project would collapse, but I soon realized it was doomed to success. Almost anything in software can be implemented, sold, and even used given enough determination. There is nothing a mere scientist can say that will stand against the flood of a hundred million dollars. But there is one quality that cannot be purchased in this way—and that is reliability. The price of reliability is the pursuit of the utmost simplicity. It is a price which the very rich find most hard to pay.

All this happened a long time ago. Can it be regarded as relevant in a conference dedicated to a preview of the Computer Age that lies ahead? It is my gravest fear that it can. The mistakes which have made in the last twenty years are being repeated today on an even grander scale. I refer to a language design project which has generated documents entitled *strawman, woodenman, tinman, ironman, steelman, green* and finally now Ada. This project has been initiated and sponsored by one of the world's most powerful organizations, the United States Department of Defense. Thus it is ensured of an influence and attention quite independent of its technical merits, and its faults and deficiencies threaten us with far greater dangers. For none of the evidence we have so far can inspire confidence that this language has avoided any of the problems that have afflicted other complex language projects of the past.

There is nothing a mere scientist can say that will stand against the flood of a hundred million dollars.

I have been giving the best of my advice to this project since 1975. At first I was extremely hopeful. The original objectives of the language included reliability, readability of programs, formality of language definition, and even simplicity. Gradually these objectives have been sacrificed in favor of power, supposedly achieved by a plethora of features and notational conventions, many of them unnecessary and some of them, like exceptions handling, even dangerous. We relive the history of the design of the motor car. Gadgets and glitter prevail over fundamental concerns of safety and economy.

It is not too late! I believe that by careful pruning of the Ada language, it is still possible to select a very powerful subset that would be reliable and efficient in implementation and safe and economic in use. The sponsors of the language have declared unequivocally, however, that there shall be no subsets. This is the strangest paradox of the whole strange project. If you want a language with no subsets, you must make it *small.*

You include only those features which you know to be needed for *every* single application of the language and which you know to be appropriate for *every* single hardware configuration on which the language is implemented. Then extensions can be specially designed where necessary for particular hardware devices and for particular applications. That is the great strength of Pascal, that there are so few unnecessary features and almost no need for subsets. That is why the language is strong enough to support specialized extensions—concurrent Pascal for real-time work, Pascal Plus for discrete event simulation, UCSD Pascal for microprocessor work stations. If only we could learn the right lessons from the successes of the past, we would not need to learn from our failures.

And so, the best of my advice to the originators and designers of Ada has been ignored. In this last resort, I appeal to you, representatives of the programming profession in the United States, and citizens concerned with the welfare and safety of your own country and of mankind: do not allow this language in its present state to be used in applications where reliability is critical, ie, nuclear power stations, cruise missiles, early warning systems, anti-ballistic missile defense systems. The next rocket to go astray as a result of a programming language error may not be an exploratory space rocket on a harmless trip to Venus. It may be a nuclear warhead exploding over one of our own cities. An unreliable programming language generating unreliable programs constitutes a far greater risk to our environment and to our society than unsafe cars, toxic

pesticides, or accidents at nuclear power stations. Be vigilant to reduce that risk, not to increase it.

Let me not end on this somber note. To have our best advice ignored is the common fate of all who take on the role of consultant, ever since Cassandra pointed out the dangers of bringing a wooden horse within the walls of Troy. That reminds me of a story I used to hear in my childhood.

The Emperor's Old Clothes

Many years ago, there was an Emperor who was so excessively fond of clothes that he spent all his money on dress. He did not trouble himself with soldiers, attend banquets, or give judgment in court. Of any other king or emperor one might say, "He is sitting in council," but it was always said of him, "The emperor is sitting in his wardrobe." And so he was. On one unfortunate occasion, he had been tricked into going forth naked to his chagrin and the glee of his subjects. He resolved never to leave his throne, and to avoid nakedness, he ordered that each of his many new suits of clothes should be simply draped on top of the old.

Time passed away merrily in the large town that was his capital. Ministers and courtiers, weavers and tailors, visitors and subjects, seamstresses and embroiderers, went in and out of the throne room about their various tasks, and they all exclaimed, "How magnificent is the attire of our Emperor."

One day the Emperor's oldest and most faithful minister heard tell of a most distinguished tailor who taught at an ancient institute of higher stitchcraft, and who had developed a new art of abstract embroidery using stitches so refined that no one could tell whether they were actually there at all. "These must indeed be splendid stitches," thought the minister. "If we can but engage this tailor to advise us, we will bring the adornment of our Emperor to such heights of ostentation that all the world will acknowledge him as the greatest Emperor there has ever been."

So the honest old minister engaged the master tailor at vast expense. The tailor was brought to the throne room, where he made obeisance to the heap of fine clothes which now completely covered the throne. All the courtiers waited eagerly for his advice. Imagine their astonishment when his advice was not to add sophistication and more intricate embroidery to that which already existed, but rather to remove layers of the finery, and strive for simplicity and elegance in place of extravagant elaboration.

"This tailor is not the expert that he claims," they muttered. "His wits have been addled by long contemplation in his ivory tower, and he no longer understands the sartorial needs of a modern Emperor." The tailor argued loud and long for the good sense of his advice but could not make himself heard. Finally, he accepted his fee and returned to his ivory tower.

Never to this day has the full truth of this story been told: that one fine morning, when the Emperor felt hot and bored, he extricated himself carefully from under his mountain of clothes and is now living happily as a swineherd in another story. The tailor is canonized as the patron saint of all consultants, because in spite of the enormous fees that he extracted, he was never able to convince his clients of his dawning realization that their clothes have no Emperor.■

BYTE's Bits

Transplanted Apple Shoppe

Joesph L Rollinson is the new publisher of *The Apple Shoppe Magazine. Apple Shoppe,* which describes itself as the "journal of Apple applications," is a periodical for users of Apple II and III computers. The magazine was previously published by David Smith of Placentia, California. Mr Rollinson is a native of San Diego, California.

Apple Shoppe is published eight times a year, for a subscriber's cost of $12 in the United States. Contact *The Apple Shoppe Magazine,* POB 22026, San Diego CA 92122.■

Microcomputers and the IRS

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*Although the author is an employee of the Internal Revenue Service, the content of this article is his opinion and does not necessarily reflect the position of the United States Internal Revenue Service....*SM

The 1980s will see unprecedented growth in the use of microcomputers by small independent businesses and professional persons. With great potential for fast, accurate processing of accounting data and other types of business records at a minimal cost, microcomputers, like photocopying machines, will soon be standard equipment in most offices.

Microcomputers offer a means of simplifying record-keeping systems while producing more timely, accurate, and detailed reports than were ever possible using a manual accounting system. The greatest benefit to a small business or professional person, however, is the cost. For a cost comparable to the annual salary of a bookkeeper, the individual can purchase a hardware and software system capable of many times the work output of a single person. If the system is well planned and properly implemented, it can result in an overall cost savings and a significant increase in the usefulness and efficiency of the record-keeping system.

Traditionally, a person entering a new business works with his accountant to set up a record-keeping system that meets generally accepted accounting principles and practices. These systems provide a logical method of tracing detailed records such as invoices and vouchers through the accounting process to the final financial reports. The systems usually produce a general ledger which is supported by subsidiary ledgers or such journals as Accounts Receivable and Accounts Payable. These, in turn, provide a complete listing of the detailed records. Thus, with the traditional method it is possible to trace an individual detailed record through the entire system. This system of tracking records is known as the "Audit Trail."

As more and more business and professional people acquire and learn to program their microcomputer systems, there may be a temptation to simplify record-keeping systems to the point where the Audit Trail is lost. For example, an individual might be tempted to write a program that would simply require the input of detailed records and would produce completed financial statements as output. While such a program would be very simple to write and even simpler to operate, it would completely eliminate any form of Audit Trail.

The lack of an Audit Trail creates two major problems: First, any error or discrepancy on the original detailed record would be impossible to locate without a complete reconstruction of all detailed records. Suppose you had such a simplified program for your Accounts Receivable. Each day, week, or month you would key in new charges and payments on account. At the end of the period your simple system would produce a statement for each customer, without any reference to the original detailed records. Such a program might work well as long as no errors were made in entering the detailed records. What would happen, however, if one of your customers paid $50 on his account and you recorded $5? Without a reference to any records, you would need to manually reconstruct the customer's entire account to verify whether or not he had, in fact, paid $50. Not only would the process be time-consuming—it would create a relation problem with the customer because of the original error.

The second problem with such a program is that it is unacceptable to the Internal Revenue Service. Section 6001 of the Internal Revenue Code of 1954 requires, in part, that "every person liable for any tax imposed by this title, or for the collection thereof, shall keep such records, render such statements, make such returns and comply with such rules and regulations as the Secretary may from time to time prescribe." Under the authority of this code section, the Internal Revenue Service has issued Revenue Procedure 64-12 (Cumulative Bulletin 1964-1, Part 1, page 672), which defines "guidelines for record requirements to be followed in cases where part or all of the account records are maintained within automatic data processing systems." The Internal Revenue Service has also issued Revenue Ruling 71-20 (Cumulative Bulletin 1971-1, page 392), which holds that "punched cards, magnetic tapes, disks, and other machine-sensible data media used in the automatic data processing of accounting transactions constitute records within the meaning of section 1.6001-1 of the regulations." Let us see how this Revenue Procedure and Revenue Ruling affect the busi-

ness or professional person using a microcomputer in his business.

Revenue Procedure 64-12 deals directly with the need for an Audit Trail in an accounting system. Section 1.01 of the Revenue Procedure states its purpose:

Section 1. Purpose

.01 *The purpose of this Revenue Procedure is to set forth guidelines specifying the basic record requirements which the Internal Revenue Service considers to be essential in cases where a taxpayer's records are maintained within an automatic data processing (ADP) system. References here to ADP systems include all accounting systems which process all or part of a taxpayer's transactions, records, or data by other than manual methods.*

Section 3 states the objectives of the Revenue Procedures:

Section 3. Objectives

....The ability to provide in legible form the data necessary to determine at a later date whether or not the correct tax liability has been reported must be carefully considered in designing and programming a machine system. This factor may add to the complexity of the system and require additional cost, but this cost may be negligible in comparison to the expense that may be incurred at a later date if the system cannot practically and readily provide the information needed to support and substantiate the accuracy of the previously reported tax liability.

(Emphasis supplied.)

Section 4 gives the specific record requirements that the Internal Revenue Service considers essential in any ADP accounting system:

Section 4. ADP Record Guidelines

.01 *...A computer's accounting program must include a method of producing from the punched cards or tapes visible and legible records which will provide the necessary information for the verification of the taxpayer's tax liability.*

.02 *General and Subsidiary Books of Account.—A*
(1) *general ledger, with source references, should be written out to coincide with financial reports for tax reporting periods. In cases where subsidiary ledgers are used to support the general ledger accounts, the subsidiary ledgers should also be written out periodically.*

(2) *Supporting Documents and Audit Trail.—The audit trail should be designed so that the details underlying the summary accounting data, such as invoices and vouchers, may be identified and made available to the Internal Revenue Service upon request.*

(3) *Recorded or Reconstructible Data.—The records must provide the opportunity to trace any transaction back to the original source or forward to a final total. If printouts are not made of transactions at the time they are processed, then the system must have the ability to reconstruct these transactions.*

Revenue Ruling 71-20 clarifies the term "records" as used in Code Section 6001:

....It is held that punched cards, magnetic tapes, disks, and other machine-sensible data media used for recording, consolidating, and summarizing accounting transactions and records within a taxpayer's automatic data processing system are records within the meaning of section 6001 of the Code and section 1.6001-1 of the regulations and are required to be retained so long as the contents may become material in the administration of any internal revenue law...

Both the Revenue Procedure and the Revenue Ruling are well known to most large companies using computer systems in their accounting process, but they may not be as well known to the small business using mini- and microcomputer systems. These businesses should check the following items in order to be sure their systems meet the requirements of the Internal Revenue Service:

- Any system or program should preserve the integrity of the Audit Trail so that any summary total may be traced back to the original detailed records, and any detailed record may be traced forward to the summary total.
- If the system or program does not produce printouts of the detailed transactions as they are processed, then the system or program must have the ability to reconstruct these transactions at the request of the Internal Revenue Service.
- If the system or program maintains accounting records on machine-sensible data media, such media are considered records and must be maintained for the same period of time as a hard-copy printout.
- Finally, if the system or program does maintain such machine-sensible data media, the system or program must include a method of producing visible and legible printouts of the media.

This article may raise more questions than it has answered. What should you do if you have questions about your system? A final quote from Revenue Ruling 71-20:

...taxpayers who are in doubt as to which records are to be retained or who desire further information should contact their District Director for assistance. ■

Technical Forum

Add Dual Trace and Delayed Sweep to Your Oscilloscope

Robert J Stetson, BASF Systems
Crosby Dr, Bedford MA 01730

Occasionally the need arises to make timing comparisons between two signals with an interval delay. However, with a conventional oscilloscope you cannot scan a looped serial-data exchange with the clock in registration and still look at the data that occurs 40 bytes later. In this situation, you may want to build an add-on unit that converts your present single-channel scope to a digital dual-trace scope with delayed sweep for about $15.

Theory of Operation—Data Multiplexer

Figures 1 and 2 show the complete logic diagram of the unit. Figure 2 is a simple, stable, clock circuit. A *chopping* frequency of 1 F CLK was selected, since it is common among dual-trace scopes. The 555 integrated circuit is used as a free-running timer that generates 2 F CLK. Since the output of the 555 is highly asymmetrical, it runs at twice the desired rate, and 2 F CLK is fed to the input of a 74LS74-type D edge flip-flop. The 74LS74 is wired as a divider and neatly converts the pulse train from the 555 timer into a perfectly symmetrical square wave of half the frequency of 2 F CLK. It is important that 1 F CLK be symmetrical to insure that the two traces have the same relative brightness. This brightness is a direct function of the sample time (controlled by 1 F CLK) for each channel.

In figure 1, 1 F CLK enables the channel 1 NAND gate (74LS00) when high, and enables the channel 2 NAND gate (74LS00) through a 74LS04 inverter when low. The two channels are multiplexed into a single signal on pin 11 of the 74LS00, an active low NOR gate.

Vertical separation of the traces can best be understood by walking through the circuit with 0V input to both channels. If both inputs stay at a low level, the output on pin 11 of the 74LS00 NOR gate stays low. Even though there is no signal, the output signal, SCOPE, will switch at 1 F CLK speed.

The diagrams in figure 4 show the relationship between the 100 k-ohm 1 F CLK leg of the summing network and the 150 k-ohm DATA leg. With 1 F CLK in a low logic state, the DATA input selects one of the two possible zones in the channel 2 area of the screen. With 1 F CLK high, the DATA input selects one of the two channel 1 areas of the screen:

Where DATA is low, DATA = 0 V
Where 1 F CLK is low, 1 F CLK = 0 V
Where DATA is high, DATA ≈ 2 V
Where 1 F CLK is high, 1 F CLK ≈ 3 V

The output from the summing network is one of the four possible combinations:

low + low	= channel 2 low	0 + 0 = 0 V
low + high	= channel 2 high	0 + 1 = 2 V
high + low	= channel 1 low	1 + 0 = 3 V
high + high	= channel 1 high	1 + 1 = 5 V

Even though half of the oscilloscope display time is spent on the upper area of the screen and half on the lower, the traces appear as two solid lines, because the 1 F CLK is synchronized with the two channel inputs, but not with the scope. The chopping frequency free-runs with relationship to the horizontal-sweep frequency of the scope, which is synchronized only with the signal at the input to channel 1.

Any attempt to synchronize on the signal at the multiplexer's SCOPE output will fail. The multiplexing action only allows you to synchronize on 1 F CLK; otherwise, as the two channels of data race across the screen they will be out of synchronization with the horizontal oscillator in the scope. A sample of the signal on which you want to synchronize is taken from the channel 1 input *before* it gets chopped by the multiplexer. This signal is then coupled by the trigger-control circuit to the scope's SYNC or TRIGGER input.

Trigger Control Circuit Theory

When INT (internal trigger) is used, the channel 1 probe should always be on the signal from which you want to synchronize. The 74LS04 inverter at the channel 1 input buffers the input signal so that the circuit being sampled does not see the added load of the extra circuitry. The second 74LS04 reinverts the signal to its true polarity.

Inverters are placed in the channel 2 signal path to balance the gate delays between the two channels. This ensures accurate results, regardless of the quality of the scope.

Another 74LS04 inverter gates the signal over to a switch where either NORMAL trigger mode or DELAYED SWEEP is selected.

With the MODE switch in the NORM position, the

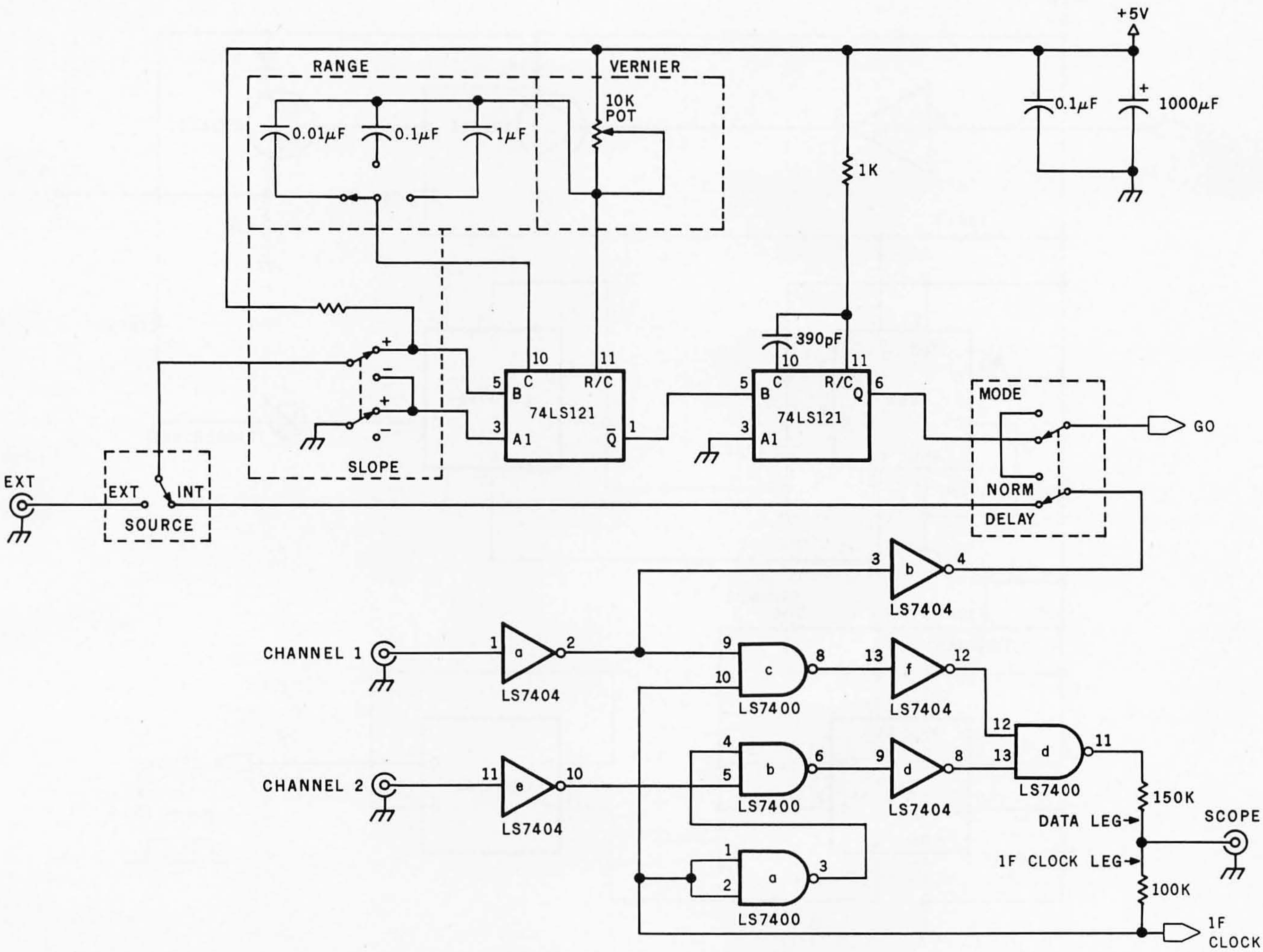


Figure 1: *Multiplex interface schematic for adding dual trace and delayed sweep to an oscilloscope. See text for details on how the circuit works.*

trigger signal is switched straight through to the 74LS04 inverter, which drives the 2N2222 transistor output-driver.

The TRIGG output is monitored by the coupling capacitor, which sets off the trigger timer and lights the trigger LED (light-emitting diode). The 74LS74 driving the trigger LED acts as an inverter: with its preset and clear inputs both low, the output on Q and $\overline{Q}$ are high. But, when the clear input goes high, the output $\overline{Q}$ goes low. In this way, the $\overline{Q}$ output will always be the inverse of the clear input, while the Q output remains high at all times. As long as the trigger LED remains lit, the scope is being triggered.

With the MODE in the DELAY position, the trigger pulses are routed through the SLOPE switch. The SLOPE switch directs the pulse to either the A or B input of a 74L121 monostable multivibrator.

I chose a 74L121 over other multivibrators because it is not retriggerable. While a 74LS123 would reduce the parts count, recurring triggers would extend the delay time indefinitely.

By using the RANGE and VERNIER controls, you can adjust the delay time. These controls increase or decrease the time from the selected edge of the triggering pulse to the timeout of the first stage of the timer chain. The second 74L121 fires when the first one times out. The second emits a short spike from which to trigger the scope.

An additional feature, the SOURCE switch, allows you to trigger from an independent source. This may be an index pulse, sector pulses or other reference signals from equipment you are working on.

Mastering the use of this unit requires patience. For instance, the channel 1 trigger source can be used only in certain applications. Other applications are best served by the external trigger option. Under certain conditions during the delayed-sweep mode, a vertical line appears on the left edge of the screen, caused by the deflection of the beam in the absence of a horizontal trace.

Since this add-on unit can only be used on logic-level signals, the unit under test can supply power. No internal power supply is shown, but you may prefer to add one.

The true amplitude of the signals on the SCOPE output will be less than the 2 V, 3 V, and 5 V levels in the description given here, because the output of the TTL devices during their source mode are less than the supply voltage. Also, the resulting voltage will be further reduced by the input impedance of the scope.

Caution: If you're tempted to cut up the front panel of

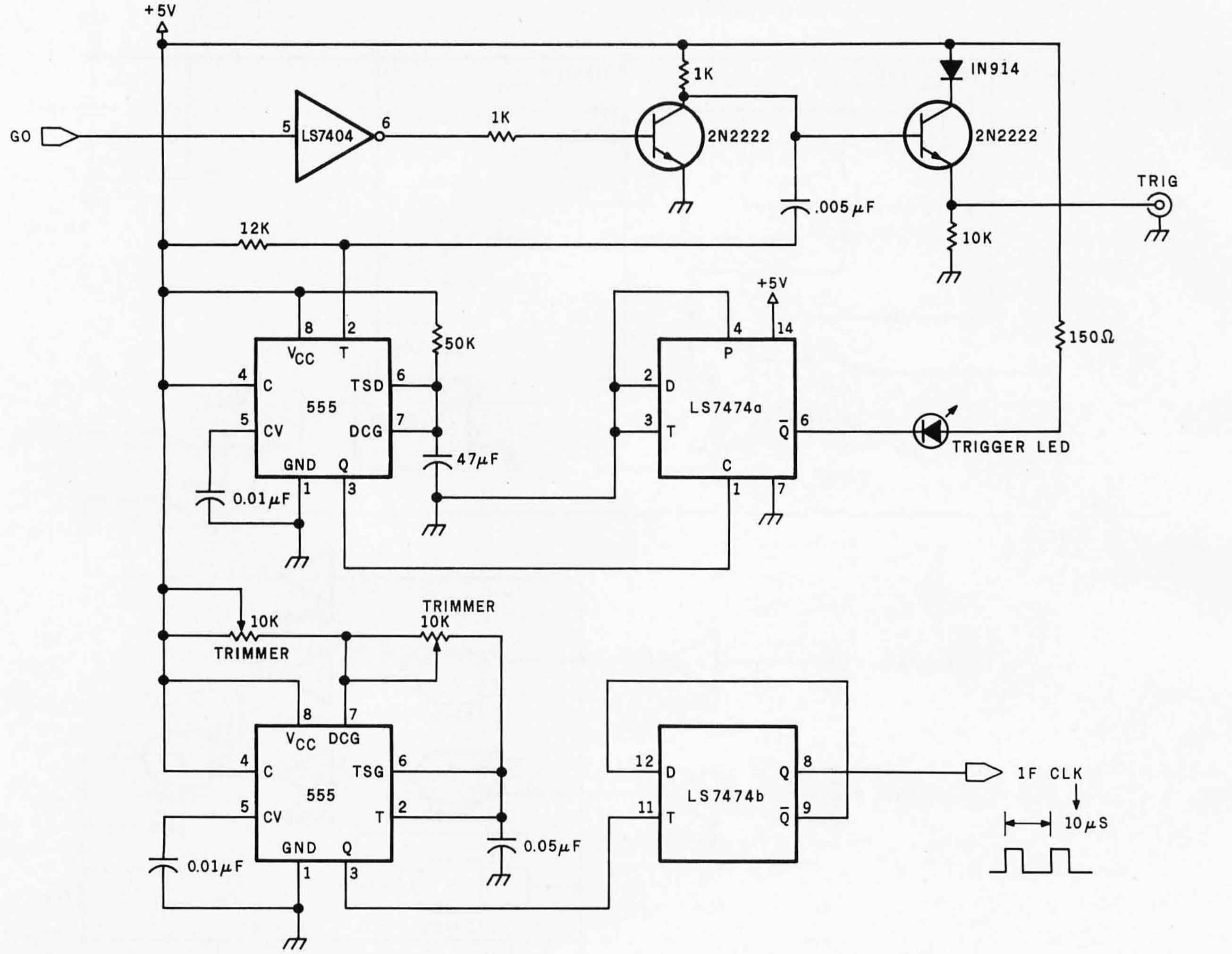


Figure 2: *Clock and trigger circuit.*

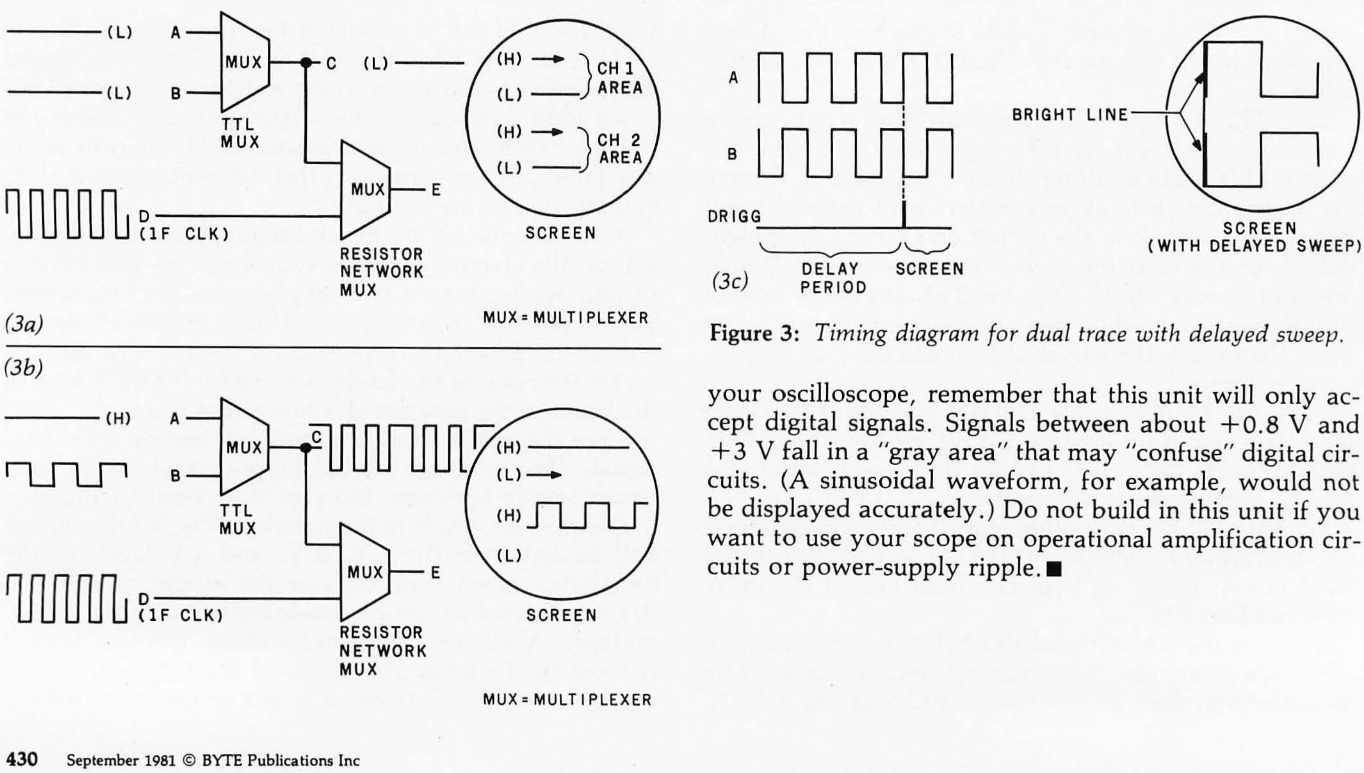


Figure 3: *Timing diagram for dual trace with delayed sweep.*

your oscilloscope, remember that this unit will only accept digital signals. Signals between about +0.8 V and +3 V fall in a "gray area" that may "confuse" digital circuits. (A sinusoidal waveform, for example, would not be displayed accurately.) Do not build in this unit if you want to use your scope on operational amplification circuits or power-supply ripple. ■

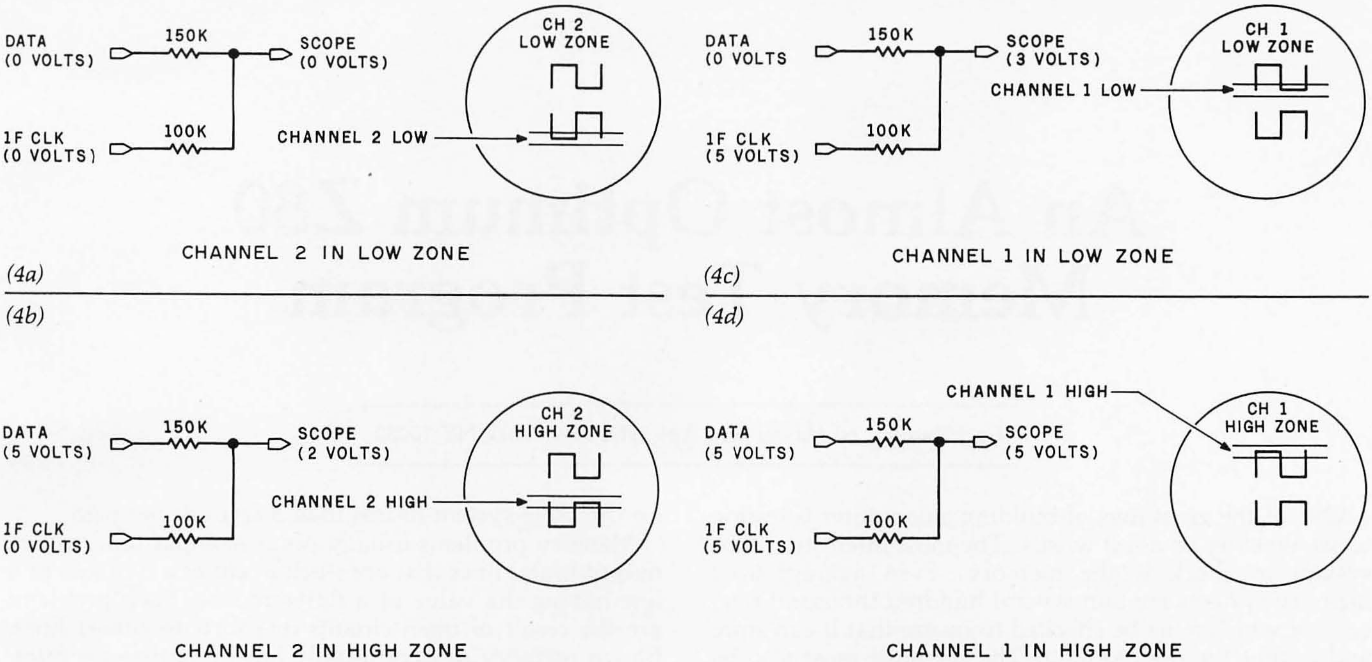


Figure 4: *Operation of the circuit shown in figures 1 and 2. Each of the four input conditions decodes to four different zones on the oscilloscope screen.*

An Almost Optimum Z80 Memory Test Program

Ira J Rampil, 60 Haven Ave Apt 15D, New York NY 10032

One of the great joys of building a computer is testing to see whether or not it works. The most interesting subsystem to check is the memory. Even average-sized memory systems contain several hundred thousand bits, each of which must be checked to insure that it can store and output the desired data. The memory must also be tested to confirm both the uniqueness of the address and the absence of bit-to-bit interference. Problems such as printed-circuit-board shorts and decoder-circuit bugs can cause data access at one address to disturb data at an entirely different address. Decoder-circuit bugs are usually encountered when a new memory is first brought up, but printed-circuit-short problems can and do occur at any time. Most memory component failures also occur early.

It is not feasible to detect and localize any but the most severe problems through the use of manual hardware debugging techniques. Memory bugs are best found by using software techniques, provided that plugging the questionable boards into the system bus doesn't cause the whole system to crash. As long as the processor, some peripherals, and at least some memory are up, programs can be loaded and run to test the remaining memory.

The most obvious test is to store all possible combinations of bits. Unfortunately there are 2^{262144} possible combinations in a 32 K- by 8-bit memory. To test each possible combination separately would take a length of time significantly greater than the projected duration of the universe.

A great deal of research has been done in order to find tricks that will shorten the time required to test memory, but many manufacturers and suppliers of microcomputer kits seem unaware of the results. For example, I recently built a system kit that was supplied with a memory test program that counted from 0 to hexadecimal FF, checking each increment in every byte in memory. It took more than five minutes per pass in my 34 K memory, and the program *failed* to detect four address-line foil bridges, one solder splash, and the bad decoder chip that mapped two 8 K boards into the same memory location. It *did* locate a data-to-address foil short and a few bad memory chips, but the program crashed after every bug it caught. By contrast, the program I'm about to describe can detect all of these problems and most others, except certain bit-to-bit interference problems, within a single byte. It runs on the same system in less than 3 seconds per pass.

Memory problems usually occur as input (address) or output (data) lines that are stuck at either a 0 or a 1, or a line having the value of a different line. Such problems are the result of open circuits or shorts to power lines. Blown memory devices usually have bits that are internally shorted or open. It should be understood that memory test programs will detect these problems and usually supply the offending addresses, but will almost never diagnose the problem. Diagnosis remains a human function that uses clues provided by memory test and dump routines. After localizing a bug, successive dumps of the offending area of memory while changing data at that address will reveal patterns characteristic of the particular bug.

The program described here is based on an algorithm described by John Knaizuk and C R P Hartmann (*IEEE Transactions on Computers*, April 1977). This algorithm is called optimal because it uses the minimal number of memory accesses to test the memory for all single-bit errors. It also catches many multiple-bit errors.

The memory under test is divided into three partitions based upon the byte addresses modulo 3. When a partition is accessed, all memory addresses within it are accessed. Each partition is then independently accessed. The address lines and the decoding circuits are exhaustively tested. Data lines and memory chips are also tested, to the extent that each bit must be able to write and read back both a 0 and a 1. The algorithm uses a total of four accesses per address. This corresponds to the number of accesses required to read and write a 0 and a 1 in each location.

The program shown in listing 1 was written for a Digital Group Z80 system, but it can be easily transported to other Z80 and 8080 systems. The major changes will be in the character output linkages and system utilities. I do not claim that this code is optimally short or fast. It was written to be legible, and it is fast enough and reasonably short. If an error is encountered, the offending address is printed, along with the erroneous data byte read and the correct byte. Errors do not terminate the test and an "A" is printed at the completion of the test sequence. ■

Listing 1: *A memory test program for the Z80 microprocessor. Although written for a Digital Group Z80 system, it can easily be modified for 8080 and other Z80 systems. Note the use of octal notation.*

```
ASSM  006000  100000

006000                  0100  ************************************************************
006000                  0110  *  AN ALMOST PERFECT MEMORY
006000                  0120  *  TESTER BASED ON THE K-H
006000                  0130  *  ALGORITHM. WRITTEN BY
006000                  0140  *  IRA JAY RAMPIL FOR
006000                  0150  *  THE Z-80
006000                  0160  ************************************************************
006000  315  346  0000  0170  BEGIN  CALL  ERASE                  ;CLEAR SCREEN
006003                  0175  *
006003                  0180  *  FIND TOP OF MEMORY
006003                  0185  *
006003  315  251  006   0190  MAIN   CALL  TOP
006006                  0200  *
006006                  0210  *  TEST SEQUENCE
006006                  0220  *
006006  021  001  000   0230         LD    DE,000001
006011  315  117  006   0240         CALL  WR
006014  021  002  000   0250         LD    DE,000002
006017  315  117  006   0260         CALL  WR
006022  021  000  377   0270         LD    DE,377000
006025  315  117  006   0280         CALL  WR
006030  021  001  000   0290         LD    DE,000001
006033  315  147  006   0300         CALL  RD
006036  021  001  377   0310         LD    DE,377001
006041  315  117  006   0320         CALL  WR
006044  021  002  000   0330         LD    DE,000002
006047  315  147  006   0340         CALL  RD
006052  021  000  377   0350         LD    DE,377000
006055  315  147  006   0360         CALL  RD
006060  021  001  377   0370         LD    DE,377001
006063  315  147  006   0380         CALL  RD
006066  021  000  000   0390         LD    DE,000000
006071  315  117  006   0400         CALL  WR
006074  315  147  006   0410         CALL  RD
006077  021  002  377   0420         LD    DE,377002
006102  315  117  006   0430         CALL  WR
006105  315  147  006   0440         CALL  RD
006110  076  201        0450         LD    A,301                    ;SIGNAL END OF
006112  315  372  000   0460         CALL  TV                       ;TEST TO SCREEN
006115  030  264        0470         JR    MAIN                     ;START OVER
006117                  0480  *
006117                  0490  *  SUBROUTINE TO WRITE TEST DATA
006117                  0500  *
006117  052  255  006   0510  WR     LD    HL,(START)
006122  173             0520         LD    A,E                      ;SET UP
006123  205             0530         ADD   L                        ;STARTING
006124  157             0540         LD    L,A                      ;ADDR OF
006125  174             0550         LD    A,H                      ;PARTITION
006126  316  000        0560         ADC   0
006130  147             0570         LD    H,A
006131  162             0580  WLP    LD    (HL),D                   ;WRITE LOOP
006132  043             0590         INC   HL                       ;TO FILL
006133  043             0600         INC   HL                       ;PARTITION
006134  043             0610         INC   HL
006135  170             0620         LD    A,B
006136  274             0630         CP    H
006137  330             0640         RET   C
006140  040  367        0650         JR    NZ,WLP
006142  171             0660         LD    A,C
006143  275             0670         CP    L
006144  330             0680         RET   C
006145  030  362        0690         JR    WLP
006147                  0700  *
006147                  0710  *  SUBROUTINE TO READ AND CHECK DATA
006147                  0720  *
006147  052  255  006   0730  RD     LD    HL,(START)
006152  173             0740         LD    A,E
006153  205             0750         ADD   L
006154  157             0760         LD    L,A
006155  174             0770         LD    A,H
006156  316  000        0780         ADC   0
```

Listing 1 continued on page 434

Listing 1 continued:

```
006160  147             0790            LD      H,A
006161  176             0800    RLP     LD      A,(HL)
006162  272             0810            CP      D
006163  304  203  006   0820            CALL    NZ,ERR          ;FOUND A BUG
006166  043             0830            INC     HL
006167  043             0840            INC     HL
006170  043             0850            INC     HL
006171  170             0860            LD      A,B
006172  274             0870            CP      H
006173  330             0880            RET     C
006174  040  363        0890            JR      NZ,RLP
006176  171             0900            LD      A,C
006177  275             0910            CP      L
006200  330             0920            RET     C
006201  030  356        0930            JR      RLP
006203                  0940    *
006203                  0950    *  SUBROUTINE TO PRINT ERROR MESSAGE
006203                  0960    *
006203  325             0970    ERR     PUSH    DE
006204  134             0980            LD      E,H             ;PUT OFFENDING ADDRESS ON TV
006205  315  267  001   0990            CALL    OCT
006210  135             1000            LD      E,L
006211  315  267  001   1010            CALL    OCT
006214  076  275        1020            LD      A,275           ;OUTPUT "="
006216  315  372  000   1030            CALL    TV
006221  136             1040            LD      E,(HL)          ;OUTPUT OFFENDING CONTENTS ON TV
006222  315  267  001   1050            CALL    OCT
006225  076  233        1060            LD      A,233
006227  315  372  000   1070            CALL    TV
006232  132             1080            LD      E,D             ;OUTPUT DESIRED CONTENTS
006233  315  267  001   1090            CALL    OCT
006236  305             1100            PUSH    BC
006237  006  022        1110            LD      B,22
006241  315  370  000   1120    SPACE   CALL    TV-2            ;OUTPUT SPACES TO GET NEXT
006244  020  373        1130            DJNZ    SPACE           ;LINE OF TV SCREEN
006246  301             1140            POP     BC
006247  321             1150            POP     DE
006250  311             1160            RET
006251  001  377  207   1170    TOP     LD      BC,207377       ;MY SYSTEM'S TOP OF MEMORY
006254  311             1180            RET
006255                  1190    *
006255                  1200    *  TV IS A ROUTINE THAT OUTPUTS
006255                  1210    *  THE CONTENTS(CHARACTER) OF A
006255                  1220    *
006255                  1230    TV      EQU     372
006255                  1240    *
006255                  1250    *  OCT IS A ROUTINE THAT CONVERTS THE
006255                  1260    *  CONTENTS OF E FROM BINARY TO OCTAL
006255                  1270    *  AND THEN PRINTS IT ON TV
006255                  1280    *
006255                  1290    OCT     EQU     001267
006255                  1300    *
006255                  1310    *  ERASE IS A ROUTINE THAT ERASES
006255                  1320    *  THE SCREEN
006255                  1330    *
006255                  1340    ERASE   EQU     346
006255  270  006        1350    START   DW      006270
```

How to Build an Inexpensive Cassette Level Indicator

Dr Milan D Chepko
119 Belleville Ct
Thief River Falls MN 56701

Looking for an inexpensive way to adjust the level of your recorder when loading programs into your microcomputer? The circuit diagram in figure 1 shows two LEDs (light-emitting diodes) and a 270- to 330-ohm resistor wired across the line from the recorder's earphone jack. The earphone or speaker is optional, but it allows you to hear the data transfer in operation. A photograph of the completed circuit is shown in photo 1.

Most microcomputers require about two volts of audio signal for reliable operation. Since LEDs "turn on" at about 1.7 V, adjust the recorder's volume control until one of the LEDs begins to flicker steadily, and you should be in business. The LEDs also seem to absorb some of the extra signal if you turn the volume up too high. ■

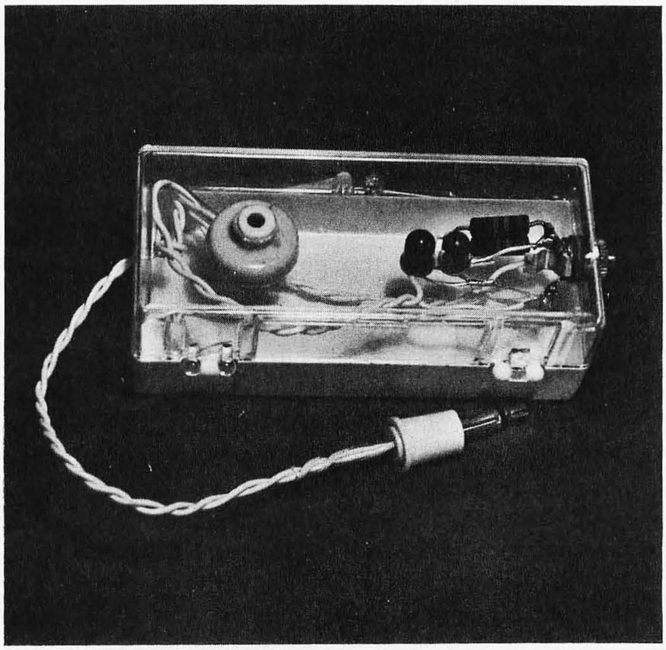


Photo 1: *The cassette level indicator built inside a small plastic box.*

Technical Forum is a feature intended as an interactive dialog on the technology of personal computing. The subject matter is open-ended, and the intent is to foster discussion and communication among readers of BYTE. We ask that all correspondents supply their full names and addresses to be printed with their commentaries. We also ask that correspondents supply their telephone numbers, which will not be printed.

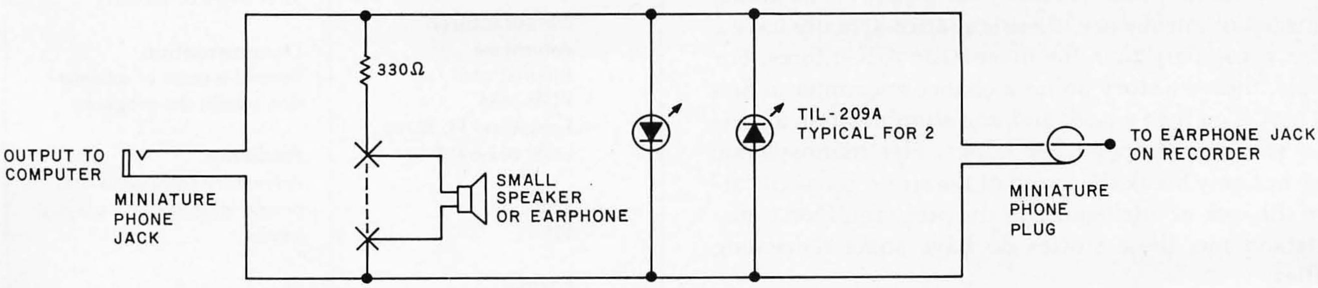


Figure 1: *Schematic diagram of the cassette level indicator.*

Interactive Fiction: Six Micro Stories

Bob Liddil, The Programmer's Guild, POB 66, Peterborough NH 03458

Adventure International has a new concept in computer simulation called Interactive Fiction. The product I'm reviewing is a sampler of six Interactive Fiction stories. The sampler is, of course, designed to whet your curiosity about the full-length titles offered by the company.

Defined in its simplest terms, an Interactive Fiction episode is a story that needs your responses to achieve its outcome. It goes far beyond Adventure's two-word responses by encouraging you to input complete sentences. I must confess that, at first, I was uncomfortable with the new format. Gradually, though, I became accustomed to bantering with the computer.

The first story places you in wartime Nazi Germany. You're an Allied spy, and you must uncover as many secrets as possible. You have been invited to a banquet, where you find yourself chatting with a high-ranking Gestapo officer. The conversation between you and the computer determines whether you live or die.

In another scenario, you are a near-bankrupt shipping tycoon entertaining a Greek billionaire. He has just made a $30 million offer for your company, but you know that in a day or so your company will be worth only $10 million. I took great delight in fleecing that fellow for $70 million.

Interactive Fiction seems to be a stylized Eliza or Dr Chips, both of which are programs that cause the computer to act as if it understands your input. While giving the illusion of intelligence, these scenarios actually have a smaller vocabulary than the most basic Adventures. For example, there's a story about a chance encounter in San Francisco. You're in a park and you stumble upon a pretty girl who has dropped her books. Her monosyllabic replies not only break the mood of the story, but sadly attest to the lack of intelligence in the program. Don't misunderstand me; these stories do have some redeeming qualities.

As in Eliza, the computer "psychiatrist," it is obvious that the program zeros in on individual words, ignoring most of the input. The rest of the stories in the sampler are similarly disappointing in their lack of versatility; there are only a couple of ways each story can be played.

I suspect that Six Micro Stories is not an adequate showcase of the Interactive Fiction concept. The stories fall far short of what the computer community expects from Scott Adams. As a party mixer or novelty, this offering will fill the bill, but don't buy this package expecting the high-quality entertainment you've received from Adventure International in the past.

Six Micro Stories should be approached as a sampler. If you expect more, you are inviting disappointment. If you want to get into the heart of this new format, you had better get Local Call for Death or Two Heads of the Coin, two full-length titles in the Interactive Fiction product line. ■

At a Glance

Name
Interactive Fiction: Six Micro Stories

Type
Adventure-type user-interactive game

Manufacturer
Adventure International
POB 3435
Longwood FL 32750
(305) 862-6917

Price
$15

Format
5-inch floppy disk

Language
Mixture of BASIC and machine code

Computer
Radio Shack TRS-80 Model I with one disk drive and 32 K bytes of memory

Documentation
Several screens of information within the program

Audience
Adventure enthusiasts and people who like role-playing games


THE ROBOT
BY TOM SLOAN
THERE! YOU ARE FINALLY FINISHED
NOW LETS SEE HOW YOU PERFORM UNDER THE ULTIMATE TEST.
WHAT'S THAT?
DO MY TAX RETURN.
SURE THING MASTER.
HMM... WHAT'S THIS!
1040
YOU KNOW, IF YOU TAKE A DEDUCTION HERE AND PUT IT IN A TAX SHELTER OVER THERE AND DO THIS AND THAT... YOU CAN CUT YOUR TAX 29.26999%.
WOW! YOU'RE KIDDING!?
NO, ITS SIMPLE AS PI.
THAT GIVES ME AN IDEA.
TAXES BY METAL MAN
FAST, PROMPT, COURTIOUS
STEP UP NOW, GET YOUR TAXES DONE!
OH BOY, IS BUSINESS GREAT!
...AND YOUR EARNED INCOME CREDIT IS EXACTLY $54.9999...
NEAT-O
GRAFIX
THANK YOU SIR. CALL AGAIN.
TOODLES
BOY MASTER, WE'RE REALLY CLEANING UP.
MAYBE NOW I CAN UPGRADE YOUR MEMORY TO 8K.
NOT SO FAST, I.R.S.
IRS ROBOT DIVISION
YOU'RE BROUGHT BEFORE THIS COURT ON CHARGES OF IMPROPER TAX RETURN PREPARATION.
YOUR HONOR, I CONTEND THAT THESE TWO KNOWINGLY AND DELIBERATELY MADE GROSS MATHEMATICAL ERRORS, LIKE $1,200-50=1,149.999!
.999! WAIT A MINUTE! WHATS 2+2?
EASY, ITS 3.9999
YEE GADS YOUR HONOR! I MUST HAVE MIS-PROGRAMED HIS MATH FUNCTIONS.
MAN IN PANIC
I CAN UNDERSTAND THAT, BECAUSE I OFTEN HAVE THE SAME PROBLEM ON MY HOME BREW SYSTEM.
SO I FIND YOU "NOT GUILTY", UNDER THE CONDITION YOU DE-BUG THE ROBOT.
YOU GOT IT JUDGEY WUDGEY!
READ ME THAT NEW LISTING. I'LL BURN IT INTO THE NEW EPROM.
0000 D8 CLD
0001 A9 01 BIP LDA $01
0003 8D 02 19 STA $1902
0006 20 81 FE JMP$ FE81
0009 D0 F6 BNE BIP
000B 29....
DONE. NOW ILL JUST PUT IT IN.
AND NOW THE TEST... WHATS 2+2?
MERE CHILDS PLAY. ITS 4.000001.
TOM SLOAN

DP/NET: Redefined

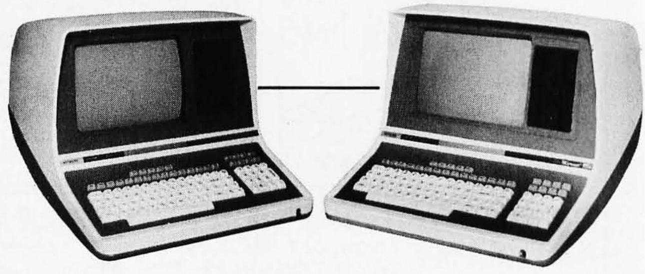
INDIVIDUAL/NET

WORD PROCESSOR

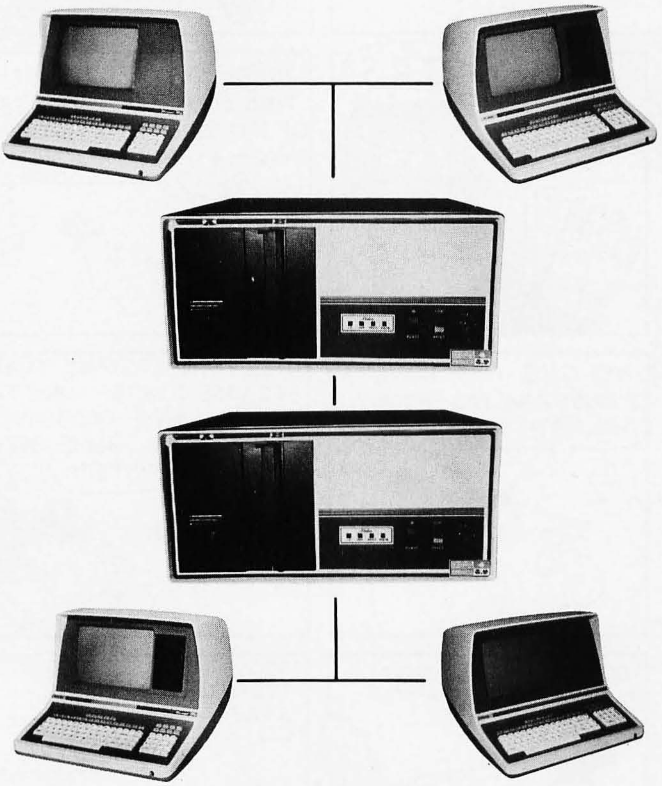
S-100, 7 Slot, 360K Double Density

DUAL/NET

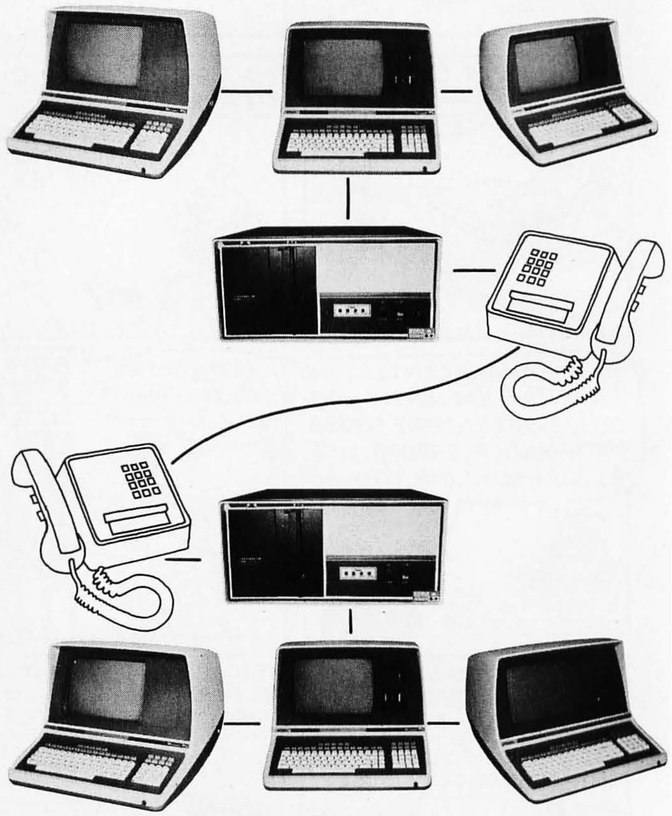
SMALL BUSINESS APPLICATIONS



Up To 4 Terminals
Can Be Slaved Off Master



LOCAL/NET



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SYSTEM/NET

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MASTER/NET

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One of the most important advantages of DP/NET® is that you never have to purchase more system than you currently need. Your system can start with a 5" minifloppy 32K terminal for under $3000.00. Adding a second terminal and additional mass storage is as simple as the original purchase. Networking up to 16 OR MORE intelligent and semi-intelligent work stations can follow in perfect step with the growth of your Company and requirements.

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Since you never buy more computer power than you need, the system cost is matched to the demand to be placed upon it. DELTA PRODUCTS has a lot of experience in building micros, with over 2000 DELTA systems now in the field. DELTA component cost has always been extremely competitive. DELTA's new "networking system" is a natural and simple combination of the competitive "good deals" we have been offering for some time.

SOFTWARE

A computer system to the end user IS THE SOFTWARE. All CP/M® compatible programs run perfectly on the DP/NET®. DELTA PRODUCTS is currently writing its' own high-performance custom data base, screen editor, order entry/inventory, and accounting packages in PL/1®. Target release date for the complete package is November, 1981.

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Circle 213 on inquiry card.

What's New?

SYSTEMS

The Stratos

The Stratos is a 4 MHz, Z80-based computer with 80 K bytes of progammable memory and 1.2 megabytes of floppy-disk storage (expandable to 5 megabytes). Stratos features a ROM (read-only memory) monitor, CP/M 2.2, the Spellbinder word-processing program, a CBASIC or a Pascal compiler, business and personal-reminder software, printer driver routines for most printers, and two RS-232C ports.

Additional features of the Stratos include a memory-mapped video controller, utilities that allow many combinations of disk drives and formats to be connected, a light pen, and an AC-controller port. The Stratos microcomputer is housed in a teakwood case. Contact Symbiotic Systems Inc, 118 Naglee Ave, Santa Cruz CA 95060, (408) 425-5533.

Circle 501 on inquiry card.

A Rair Thing Indeed

Inside Rair Microcomputer Corporation's Black Box 3/30 is a 5-megabyte Winchester hard disk and a dual-sided, double-density floppy-disk drive for backup. The Black Box 3/30 features either the CP/M or MP/M operating systems and an IEEE-488 bus with 64 K bytes of programmable memory and 16 programmable I/O (input/output) ports.

For applications and development, Rair offers BASIC, PL/1, FORTRAN, COBOL, and Pascal. The Black Box 3/30 costs $7500. Contact Rair Microcomputer Corporation, 4101 Burton Dr, Santa Clara CA 95050, (408) 988-1790.

Circle 502 on inquiry card.

Tiny BASIC Computer Board

The K-8073 single-board computer features National's INS8073 Tiny BASIC Microinterpreter microprocessor. Features include serial communication data rates from 110 to 4800 bps (bits per second), a cassette-tape I/O (input/output), 8 K bytes of EPROM (erasable programmable read-only memory), 1 K of programmable memory with expansion to 8 K externally, STD bus structure, remote controller for single-wire data control from remote stations, and 24 bidirectional I/O lines. The board is supplied with a 2 K ROM (read-only memory) of development utilities and a real-time calendar/clock.

The K-8073 requires +5 V and costs $388. Contact Transwave Corporation, RD 1 Box 489, Vanderbilt PA 15486, (412) 628-6303.

Circle 503 on inquiry card.

The LNW80 Microcomputer

The LNW80 microcomputer is software-compatible with the TRS-80. It includes a 4 MHz, Z80A microprocessor, high-resolution black-and-white and color graphics, 12 K bytes of ROM (read-only memory), 16 K bytes of programmable memory, upper- and lowercase display, reverse video, an RF (radio frequency) modulator, expansion bus, cassette interface, and power supply.

The LNW80 costs $1664 with a black-and-white monitor and a single 5-inch floppy-disk drive, but it can be purchased without peripherals for $1200. For details, contact LNW Research Corporation, 14661 C Myford Rd, Tustin CA 92680, (714) 544-5744.

Circle 504 on inquiry card.

Xerox 820 Microcomputer

The Xerox 820 microcomputer can be used as a word-processing system, a business computer, or both. The basic 820 system includes two RS-232C and two parallel ports, dual 5-inch floppy-disk drives each with a 92 K-byte unformatted capacity, a standard keyboard, and a 12-inch black-and-white video-display monitor with 24 lines by 80 characters.

The 820 features a Z80 microprocessor with 64 K bytes of programmable memory and 4 K bytes of ROM (read-only memory). The CP/M operating system and applications software, including CBASIC-2, COBOL 80, MBASIC, and word-processing programs, are available. A word-processing system utilizing WordStar and the SuperCalc electronic spreadsheet are available as options. It can be connected to the Ethernet communications network. The Xerox 820 costs $2995 and is available from Xerox and authorized dealers. For further details, contact the Office Products Division, Xerox Corporation, 1341 W Mockingbird Ln, Dallas TX 75247.

Circle 505 on inquiry card.

Sierra 4000

The Sierra 4000 computer is an S-100, Z80-based computer that features dual floppy-disk drives and a hard disk. Together, these devices provide a total of up to 96 megabytes of storage. A two-drive hard-disk system is optional.

For more information, contact Sierra National Corporation, 5037 Ruffner St, San Diego CA 92111, (714) 277-4810.

Circle 506 on inquiry card.

What's New?

SOFTWARE

MP/M-86 Operating System

Digital Research's MP/M-86 is a multiuser operating system for 8086-based microcomputers. It is compatible with the CP/M-86 operating system and programs. MP/M-86 will support networking capabilities through CP/NET. It allows multiple users to execute programs with only one copy of the object code in main memory.

Other features of the MP/M-86 operating system are file and record lockout, standard input/output, and internal queue mechanisms that support mutual exclusion, pipes, synchronization and communication between multiple tasks. Customized operating environments can be defined within the MP/M-86 structure. For more information, contact Digital Research Inc, POB 579, 801 Lighthouse Ave, Pacific Grove 93950, (405) 649-3896.

Circle 507 on inquiry card.

New Personal Software Products

Personal Software has five new items in its product line: a new version of the VisiCalc business and planning program and four new VisiCalc-compatible programs. The new VisiCalc program includes a full implementation of a program-independent data-storage format called Data Interchange Format. It allows transfers of files between VisiCalc and other text and data programs regardless of format structure. An Edit command lets users edit formulas without retyping them. Also Boolean functions and the ability to choose specific elements in a list based on the results of another calculation are featured. The new VisiCalc costs $199.95.

VisiPlot is a new VisiCalc-compatible program with high-resolution color plotting and graphics. It costs $179.95. VisiDex is a personal-information system that can handle mailing lists and personal calendars. It costs $199.95. VisiTrend/VisiPlot is a combination of VisiPlot graphics and a program for time-series manipulation, trend forecasting, and descriptive statistics. Its suggested price is $259.95. Then, there is VisiTerm, which can send and receive files from the other Visi-programs over telephone lines to any other computer. VisiTerm is $149.95.

For details, contact Personal Software Inc, 1330 Bordeaux Dr, Sunnyvale CA 94086, (408) 745-7841.

Circle 508 on inquiry card.

Music Reader

Music Reader I shows you the notes while it plays the melody through the Apple II's speaker. You can learn to read treble and bass clefs, note values, time and key signatures, sharps and flats, and complex rhythms because the program plays what you write. Music Reader I comes on a floppy disk and costs $30. Contact Shafer Software, 749 W Fremont Ave, Sunnyvale CA 94087.

Circle 509 on inquiry card.

Applesoft Compiler

The Hayden Book Company's Applesoft compiler can increase a BASIC program's speed as much as ten times and occupies only 3.2 K bytes of memory. The 17-pass compiler generates true machine code. High-resolution graphics and shape tables are supported, and multiple programs can reside in memory at the same time.

Hayden's Applesoft compiler requires a 48 K-byte Apple II Plus or Apple II with Applesoft in ROM (read-only memory), the Autostart ROM, and at least one floppy-disk drive. The compiler can be used with multiple- and hard-disk drives, and it can work on systems using the Apple Language Card or Microsoft RAM-Card. The compiler costs $200. Contact Hayden Book Company Inc, 50 Essex St, Rochelle Park NJ 07662, (201) 843-0550.

Circle 510 on inquiry card.

Air Combat Game

The Computer Air Combat game recreates World War II aerial combat. The player(s) choose from thirty-six fighters or bombers. Each plane is rated in historical accuracy and detail for firepower, speed, maneuverability, damage-tolerance, and climbing and diving ability. Five scenarios are provided to refight actual combat engagements.

Computer Air Combat includes a rule book, two map-board charts, and three player-aid charts. The game is available for 48 K-byte Apple IIs with Applesoft in read-only memory and a floppy-disk drive. It costs $59.95. Contact Strategic Simulations Inc, 465 Fairchild Dr, Suite 108, Mountain View CA 94043, (415) 964-1353.

Circle 511 on inquiry card.

What's New?

SOFTWARE

Language for Education—TI Logo

TI Logo was designed for the TI-99/4 microcomputer. It is the end result of collaboration between Texas Instruments and the Massachusetts Institute of Technology. TI Logo has been tested in schools in New York City and Dallas, Texas, with students ranging from nursery school through the twelfth grade.

TI Logo is structured so that children can successfully use the computer with little formal instruction. Students can draw geometric figures and designs and program the movement of special graphics figures. To work with the language, students must teach the computer what to do, which makes learning with TI Logo an interactive process rather than a feedback situation. Using TI Logo, students make on-the-spot judgments as to whether their approach to a problem is effective.

A TI Logo set-up requires the software and a TI-99/4 computer with a video display, floppy-disk drive and controller, and a memory-expansion unit. TI Logo software costs $299.95. For more information, contact the Customer Relations Department, Texas Instruments Inc, POB 53, Lubbock TX 79408.

Circle 512 on inquiry card.

The MDBS-QRS

The MDBS-QRS add-on lets nonprogrammers interrogate any Micro Data Base Systems data base using English-like commands. Utilities defining macroinstructions are included. Titles and synonyms for the various database entities can be defined. A report generated in response to a query can be displayed in a standard or customized format using the Report Writer feature. String comparisons are allowed, and an optional conditional clause can be included for highly selective data retrieval. Existing data values can be modified. It is available for $300 from Micro Data Base Systems Inc, POB 248, Lafayette IN 47902, (317) 448-1616.

Circle 513 on inquiry card.

CP/M Cross-Assemblers

Avocet Systems's XASM family of cross-assemblers can now run on 8080 and Z80-based microcomputers under CP/M and similar operating systems. Pseudo-operation codes support nested conditional assembly, listing-format control, definition of mnemonic synonyms, and the inclusion of external source files. The assemblers generate object files in the Intel HEX format.

Other members of the XASM family of cross-assemblers are designed for 6805, 6801, 1802, 6502, 6800, COP400, and other microprocessors. Each XASM cross-assembler costs $200; manuals cost $25. Contact Avocet Systems Inc, 804 S State St, Dover DE 19901, (302) 734-0151.

Circle 514 on inquiry card.

Music and Animation Program

Rainbow Writer is a graphics, text, music, and animation program that runs on the Apple II and the Apple II Plus computers. It can create special effects that feature color, animation, letters, shapes, and sounds. The program lets users define character fonts and choose between nine sizes and nineteen different colors of upper- and lowercase English and Greek letters. Musically, the program offers six chromatic octaves and note sustain. Music data can be stored on disk.

The suggested retail price is $39.95. For details, contact Personal Software Inc, 1330 Bordeaux Dr, Sunnyvale CA 94086, (408) 745-7841.

Circle 515 on inquiry card.

What's New?

PUBLICATIONS

Evaluation of Educational Programs

School MicroWare Reviews contains user evaluations of instructional programs and packages for the Apple, PET, and TRS-80 microcomputers. Each edition includes an index to evaluations in other publications. The reviews are organized by school department and within that by subject. Each review contains comments about the quality of the documentation, the instructions to users given by the programs, the student-computer dialogue, and other concerns. The evaluation includes the producer, price, hardware configuration, storage medium, program type, grade level, and functional description. **School MicroWare Reviews** costs $30 per edition.

Also available is the **School MicroWare Directory**. A subscription to it costs $20 per year. It contains descriptions of over 900 programs. If you are a directory subscriber and provide a courseware evaluation that follows a form provided by the publishers, you can receive **Reviews** free if your evaluation is published. Nondirectory subscribers whose material is published receive **Reviews** at half price. Contact Dresden Associates, POB 246, Department BY-1, Dresden ME 04342, (207) 737-4466.

Circle 516 on inquiry card.

Literature on Computer Science and Technology

The United States Government Printing Office has books and manuals on computer-related subjects for sale. For information on titles and ordering, contact the Superintendent of Documents, US Government Printing Office, Washington DC 20402.

Circle 517 on inquiry card.

Microsoft Catalog

Microsoft Consumer Products has a new catalog that describes all of the software products it produces and sells. The free catalog is available at Microsoft dealers or by contacting the company at 400 108th Ave, NE, Suite 200, Bellevue WA 98004, (206) 454-1315.

Circle 518 on inquiry card.

Structured Requirements Definition

Structured Requirements Definition, by Ken Orr, covers recent advances in systems theory, tools, and methodology. The book is written for analysts, programmers, managers, and users. It is available for $25 from Ken Orr and Associates Inc, 715 E 8th, Topeka KS 66607, (800) 255-2459; in Kansas (913) 233-2349.

Circle 519 on inquiry card.

Courseware Evaluation Guidelines

Guidelines for Evaluating Computerized Instructional Materials is a guide for buying and selling instructional software. Previous programming experience is not assumed in this book for users and creators of educational computer software. Divisions within the guide explain ways to determine what sort of software is needed, how to look for it, and minor modifications that can be made.

Guidelines for Evaluating Computerized Instructional Materials costs $3.75. Contact the National Council of Teachers of Mathematics, 1906 Association Dr, Reston VA 22091, (703) 620-9840.

Circle 520 on inquiry card.

FORTH Beginner's Book

Starting FORTH is for novice FORTH programmers. It embraces such topics as defining words, compiling words, vectored execution, virtual memory, and number-scaling techniques. Many programming examples and illustrations are featured. The book is published by Prentice-Hall Inc. For more information, contact FORTH Inc, 2309 Pacific Coast Hwy, Hermosa Beach CA 90254, (213) 372-8493.

Circle 521 on inquiry card.

DEC LSI/PDP-11 Systems Catalog

A catalog featuring DEC (Digital Equipment Corporation) LSI/PDP-11 computer systems, peripheral equipment, and software is available from Compumart Corporation. Compumart distributes equipment and systems from DEC and peripherals from other major manufacturers. For your copy, contact Compumart Corporation, 65 Bent St, POB 568, Cambridge MA 02139, (617) 491-2700.

Circle 522 on inquiry card.

Software Protection

The legal protection of computer software is examined in **Computers, Copyright and the Law**. This report was developed to help software authors make decisions about protecting their product's proprietary rights. The report encompasses the theories behind software protection, but it emphasizes protection methods and their relationship to software sales, leasing, and licensing. Contact Educational Programming Systems, 1328 Baur Blvd, St Louis MO 63132, (314) 991-0300.

Circle 523 on inquiry card.

What's New?

PUBLICATIONS

International Software Directory

The International Microcomputer Software Directory is a reference source of new and established software for all applications and systems. The directory is divided into sections listing programs for specific computers, describing categories of programs, and a section for users wishing to buy from a particular software house. Programs are cross-referenced throughout the sections. Details as to date of release, warranties, distributors, medium, source code, compatible systems, special configurations needed, limitations, and prices are all provided.

The directory is availalble for $29; updates are available every six months. System-specific directories that are extracted and cross-referenced from the main data base are available for $12. These directories list programs written for the Apple, TRS-80, and PET computers, and the CP/M operating system. The directory is available from Imprint Software, 420 S Howes, Fort Collins CO 80521, (303) 482-5574. In England, contact Imprint Software, 16 Milton Ave, Highgate, London, N6.

Circle 524 on inquiry card.

600 Microprocessors Cross-Referenced

The **Microprocessor IC D.A.T.A. Book** lists characteristics of over 5000 integrated circuits, including over 600 microprocessors and associated programmable and read-only memory devices, interface-support circuits, processor architecture, and manufacturer software support. Processors are cross-referenced by generic numbers, technical characteristics, logic, block drawings, instruction sets, outline drawings, and manufacturers. The book is published twice a year. The subscription rate is $55 per year. Contact D.A.T.A. Inc, POB 26875-PR, San Diego CA 92126, (800) 854-7030; in California (714) 578-7600.

Circle 525 on inquiry card.

Computer Music Journal

A special two-part issue of **Computer Music Journal**, a quarterly from MIT Press, surveys the applications of artificial intelligence to music. Articles deal with devices that will be capable of listening to, understanding and playing music, and reports on research underway that hopes to explain human musical cognition. Other topics include the use of the computer as an assistant for musical-score analysis and composition, automatic music transcription from sound to score, multilevel graphic representation of scores and sound in natural languages, intelligent music instruments, new theories of music, and an introduction to LISP.

A subscription to the **Computer Music Journal** costs $25 per year. Contact the MIT Press, 28 Carleton St, Cambridge MA 02142, (617) 253-2889.

Circle 526 on inquiry card.

Software-Vendor Directory

The fourth edition of the **Software Vendor Directory** contains 1001 software vendors, 4195 products, and 80 hardware and 200 software categories. The directory costs $57.95. Optionally, the directory can be purchased for $100, which includes two updates at six-month intervals. A single update costs $25. Also, a CP/M disk version is available for $78. Contact Micro-Serve Inc, 250 Cedar Hill Ave, Nyack NY 10960, (914) 358-1340.

Circle 527 on inquiry card.

Guide to Published Material on Computers

Bookguide 1: Microprocessors and Microcomputers covers publications that describe the concepts, applications, and potential of microprocessor devices. It lists authors, abstracts, publishers, and prices for nearly 500 titles from 39 publishers. Books on more than 50 topics ranging from histories to dictionaries, microcomputer architecture, programming techniques, personal computers, and artificial intelligence, are listed. **Bookguide 1** is available for $11.50 from Leatherleaf Book Services Inc, POB 28, Pembina ND 58271.

Circle 528 on inquiry card.

Books for the Apple

MICRO/Apple 1 is the first volume of a series of books that will contain articles from **Micro, The 6502 Journal**. The articles contain Apple program listings, which are on a floppy disk that accompanies the book. **MICRO/Apple 1** costs $24.95, including the disk. Contact Micro Ink Inc, POB 6502, Chelmsford MA 01824.

Circle 529 on inquiry card.

What's New?

PERIPHERALS

Connect an Olympia ES100 to a Microcomputer

Using the Ren Tec RS-232C interface, the Olympia ES100 typewriter can provide letter-quality printing and still function as a standard typewriter. The Ren Tec RS-232C uses CMOS (complementary metal-oxide semiconductor) logic. It accepts an RS-232C serial or a parallel interface; accommodates odd, even, or no parity; features handshake logic; and also provides any character-translation format.

The Ren Tec ES costs $295. For additional details, contact Renaissance Technology Corporation, 3347 Vincent Rd, Pleasant Hill CA 94532, (415) 930-7707.

Circle 530 on inquiry card.

Color Printer for the Apple

The OmniColor II is a color-ink jet printer with a 16 K- or 32 K-byte buffer. Intended for the Apple II, software for 3.3 DOS is included. The OmniColor II uses eight colors, prints at 40 cps (characters per second), and can print paper up to 13 inches wide, as well as print overlay pages and screens. It features normal or expanded print and the ability to dot-plot any section of memory. Contact Omnico Computer Corporation, 3300 Buckeye Rd, Atlanta GA 30341, (404) 455-8460.

Circle 532 on inquiry card.

Double Your Graphics Capability

The Double Hi-Res card provides two levels of grey scale and can display 80 columns by 24 lines. It is designed for the Apple II or III and is compatible with the Apple III's super-high-resolution graphics. Character sets can be defined with the Define Font program supplied. The Double Hi-Res features italics, underline, multiple-character sets as well as graphics on the same screen, proportional spacing, mathematics symbols, and APL- and Japanese-character sets. Multiple-character sets can reside in memory simultaneously.

The price for the Double Hi-Res card and support software on a floppy disk is $295. Contact Spies Laboratories, POB 336, Lawndale CA 90260, (213) 644-0056.

Circle 533 on inquiry card.

The Rhythm Box

The Rhythm Box synthesizes bass and snare drums, wood blocks, short and long cymbals, hand claps, and tom-toms. It is programmable in Level II BASIC or assembly language. The unit has a phono jack for connection to an audio system, a power supply, a manual including BASIC and assembly-language software examples, and a selection of rhythm charts. The Model RBX-T for the TRS-80 Model I Level II is available for $149.

The Model RBX-S is for S-100, Apple II, PET, and other systems. It connects to 9600 bps (bit per second) serial interfaces using either RS232C or 20 mA current-loop levels. It costs $179. For more information, contact Newtech Computer Systems Inc, 230 Clinton St, Brooklyn NY 11201, (212) 625-6220.

Circle 531 on inquiry card.

Thin Floppy-Disk Drives

The Thinline 8-inch floppy-disk drives are 5.9 cm ($2\frac{3}{10}$ inches) high and weigh 7 pounds. These double-sided head drives can be turned on and off by control signals from the interface. Head positioning is accomplished by a band-driven carriage. The door arrangement has been simplified by using a lever that closes and positions the disk in the drive. The Thinline drives record at 48 and 96 tracks per inch.

There are two models available. The TM 848-1 stores 600 K bytes on one side of a disk and TM 848-2 stores 1.2 megabytes on both sides. The drives can be used in single- and double-density applications. For more information, contact Tandon Corporation, 20320 Prairie St, Chatsworth CA 91311, (213) 993-6644.

Circle 543 on inquiry card.

11 by 11 Digitizer

The Demi-Pad is an 11- by 11-inch digitizer tablet featuring a 200-sample-per-second rate. It includes a Z80-based interface, which provides RS-232C ASCII (American Standard Code for Information Interchange) or binary-coded data, and 0.001-inch resolution. The Demi-Pad comes with a pen or stylus cursor.

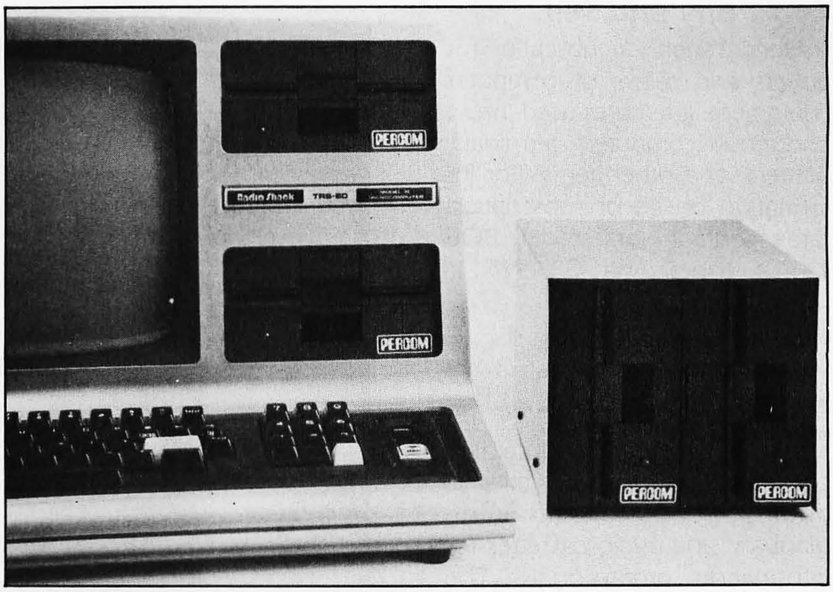
Options include a power supply, 16-button stylus or crosswire cursor, X Y display, and an ASCII keyboard. Priced at $990, the Demi-Pad is available from GTCO Corporation, 1055 First St, Rockville MD 20850, (301) 279-9550.

Circle 534 on inquiry card.

What's New?

MISCELLANEOUS

5-Inch Drives for the TRS-80 Model III



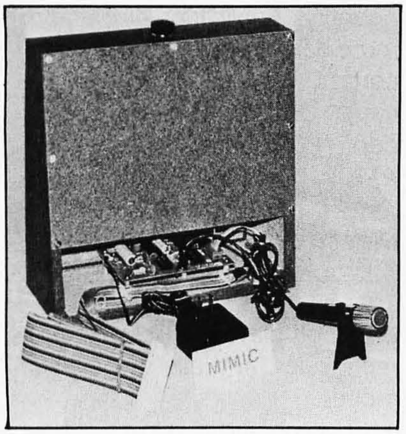
Percom Data Company has 5-inch floppy-disk drives for the TRS-80 Model III. Systems can be ordered with either 40- or 80-track drives rated for double- and single-density operation. The first two drives mount inside the computer; the others mount externally. The first internal drive comes with a four-drive controller, a two-drive power supply, cables, a double-density disk operating system, and mounting hardware.

The four-drive controller features data-separation and write-precompensation circuitry. It is capable of handling two-headed drives and single-density 8-inch drives. The computer can use the Model III's disk operating system or Percom's OS-80/III. The first internal drive sells for \$749.95 in the 40-track version and \$914.95 in the 80-track version.

The second internal drive includes the drive mechanism, electronics, and installation hardware. It costs \$315 in the 40-track version and \$474.95 in the 80-track version.

Single external 40-track drives are \$439, and the dual 40-track drives are \$878. Cables for the external drives are \$29.95. For details, contact Percom Data Company Inc, 211 N Kirby, Garland TX 75042, (800) 527-1592; in Texas, (214) 272-3421.

Circle 535 on inquiry card.



Speech Processor

The Mimic speech processor converts speech to digital data and reconstructs the digital representation to analog form for reproduction through a speaker. The system can be used for digital speech-communications applications without a computer. The speech data rate is user-selectable, with speech reproduced at rates from 9600 to 20,000 bps (bits per second).

There are four versions of the Mimic speech processor: a \$20 bare board, an assembled and tested module for \$79, a \$149 system configured for parallel-port interfacing, and a TRS-80-compatible plug-in version for \$169. Documentation, including program examples and schematics for an S-100 bus interface, is also available. Contact Mimic Electronics Company, POB 921, Acton MA 01720.

Circle 536 on inquiry card.

Small-Systems Software and Services Sourcebook

Small Systems Software and Services Sourcebook lists and cross-indexes software and services available to users of mini- and microcomputers in business, professions, and government. Entries include software and service listings related to system software, application software, and consulting and services in medical, business, investment, modeling, and other applications. The book has some marketplace listings and display advertising. For more information, contact Information Sources Inc, 1807 Glenview Rd, Glenview IL 60025, (312) 724-9285.

Circle 537 on inquiry card.

What's New?

MISCELLANEOUS

Buy and Sell

Horsetrader is a publication for buyers and sellers of computer equipment. It features used, new, and rebuilt computers, terminals, printers, and other items. For information on ad or subscription rates, contact **Horsetrader**, POB 11712, Santa Ana CA 92711, (714) 832-0628.

Circle 538 on inquiry card.

Book Catalog

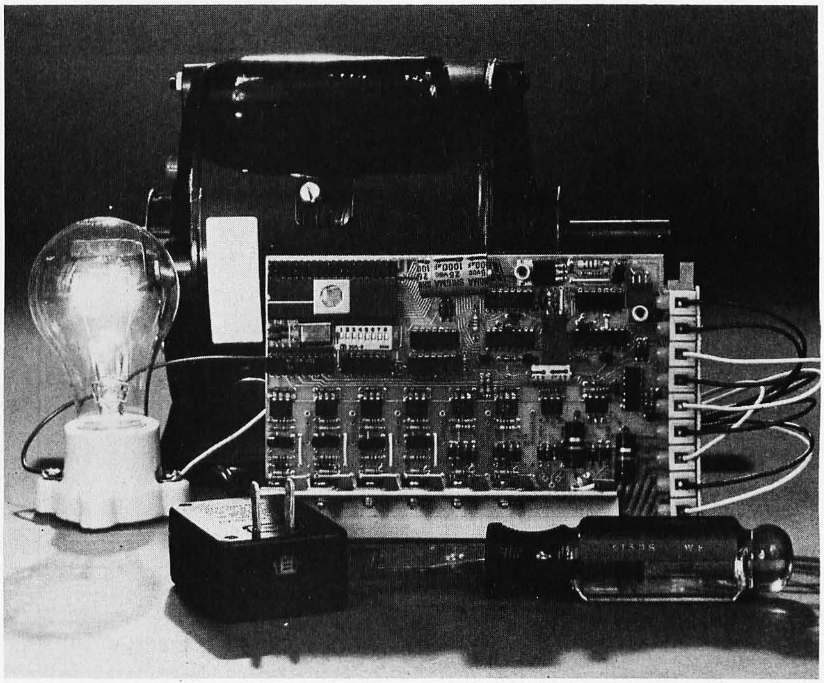
Telecom Library's 1981 catalog contains more than 300 titles of books, periodicals, training manuals, and audio cassettes for information professionals. The catalog features books on telecommunications management, data communications, data processing, computer programming, office automation, word processing, teleconferencing, satellites, and cable television. The catalog is free from Telecom Library Inc, 205 W 19th St, New York NY 10011, (212) 691-8215.

Circle 539 on inquiry card.

CBASIC Program Directory

Compiler Systems Inc has published a directory listing 157 business-application programs as well as vertical-market packages written in CBASIC available from 30 software vendors. **The CBASIC Software Directory** provides a description of each program, its memory requirements, and the vendor's name, address, and telephone number. Unless noted, all products support CP/M and MP/M and require at least one floppy-disk drive. The directory is available for $14.95 from Compiler Systems Inc, 37 N Auburn Ave, POB 145, Sierra Madre CA 91024, (213) 355-1063.

Circle 540 on inquiry card.



Single-Board Computer

A single-board computer with analog, serial, and power-control I/O (input/output) has been announced by Wintek. The board features a 6801 or 68701 microprocessor with 2 K bytes of ROM (read-only memory), 128 bytes of programmable memory, and an internal and an external timer. The 12-bit A/D (analog-to-digital) converter can be configured for eight single-ended or four differential inputs. The eight digital I/O lines can be configured for any mix of AC or DC inputs or outputs. The serial I/O allows half-duplex 20 mA current-loop communication to a host computer at software-selectable rates.

The prices range from $88 to $295, depending on options and quantity. Applications include remote data acquisition, machinery control, and energy management. Contact Wintek Corporation, 1801 South St, Lafayette IN 47904, (317) 742-8428.

Circle 541 on inquiry card.

Software for the Atari

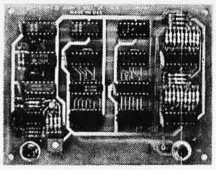
Personal Software has introduced MicroChess and Checker King for the Atari 400 and 800 microcomputers. Both games feature an on-screen, real-time clock for game timing. The games require 8 K bytes of memory and are priced at $19.95 each, on cassette.

The MicroChess program turns a color-display screen into a chessboard. It has eight selectable levels of play, plays by tournament rules, and allows no illegal moves.

Checker King allows single, double, and triple jumps, forces jumps, and performs according to the tournament rules of checkers. For details, contact Personal Software Inc, 1330 Bordeaux Dr, Sunnyvale CA 94086, (408) 745-7841.

Circle 542 on inquiry card.

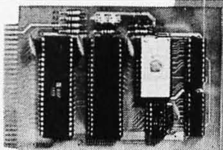
A-D & D-A CONVERTER



JBE one channel A-D & D-A Converter can be used with any system having parallel ports • Interfaces with JBE Parallel I/O Card • D-A conversion time — 5 μs • A-D conversion time — 20 μs • Uses JBE 5V power supply • Parallel inputs & outputs include 8 data bits, strobe lines & latches • Analog inputs & outputs are medium impedance 0 to 5 volt range.

79-287 ASSM. **$79.95**
Bare Board **$39.95** Kit **$59.95**

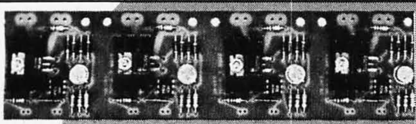
6502 MICROCOMPUTER



JBE's 4½x3¼ dedicated controller features: • 1024 bytes RAM (two 2114s) • 2048 bytes EPROM (2716) • Uses one 6522 VIA (comp. doc. incl.) • Interfaces with JBE Solid State Switches & A-D & D-A Converter • Uses JBE 5V power supply • 2716 EPROM available separately (2716 can be programmed with an Apple II & JBE EPROM Programmer & Parallel Interface) • 50 pin connector included in kit & assm.

80-153 ASSM. **$110.95**
Bare Board **$49.95** Kit **$ 89.95**

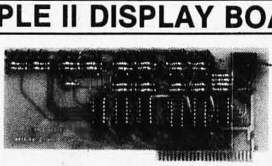
SOLID STATE SWITCH



Your computer can control power to your printer, lights, stereo & any 120VAC appliances up to 720 watts (6 amps at 120VAC). Input 3 to 15VDC • 2-14MA TTL compatible • Isolation — 1500V • Non zero crossing • Comes in 1 or 4 channel version.

79-282-1 ASSM. **$13.95**
Bare Board **$6.95** Kit **$10.95**
79-282-4 ASSM. **$49.95**
Bare Board **$24.95** Kit **$39.95**

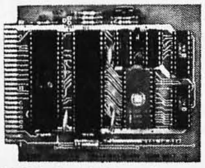
APPLE II DISPLAY BOARD



• Has run-stop, single step switch • Has 16 address LEDs, 8 data LEDs & 1 RDY LED • All lines are buffered.

80-144 ASSM. **$49.95**
Bare Board **$25.95** Kit **$42.95**

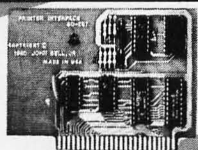
Z80 MICROCOMPUTER



JBE's 4-1/8"x3-1/4" single board dedicated computer is designed for control functions. It features: • A Z80 Microprocessor software compatible with the Z80, 8080 & 8085 Microprocessors • Uses a Z80 PIO chip for I/O which has 2 independent 8 bit bidirectional peripheral interface ports with handshake & data transfer control • Uses one 2716 EPROM (2K) & two 2114 RAM memories (1K) • Single 5V power supply at 300MA req. • Clock frequency is 2MHz, RC controlled • Board comes with complete doc. • 50 pin connector is included • 2716 EPROM available separately.

80-280 ASSM. **$129.95**
Bare Board **$49.95** Kit **$119.95**

PRINTER INTERFACE



JBE Parallel Printer Interface interfaces your Apple II® to Centronics® compatible printers. This 3" x 4" board features: on board ROM compatible with Integer Basic, Applesoft® and Pascal® • Has one 8 bit parallel latched output port with selectable positive or negative strobe and one bit input selectable for Ready or Ready • Cable and Connectors available separately.

80-297 ASSM. **$79.95**
Kit **$69.95**
4 ft. Std. Dip Jumpers 16 pin **$ 4.25**
Champ Connector **$ 9.95**

POWER SUPPLIES

• Use wall transformers for safety • Protected against short circuit and thermal breakdown.

5 VOLT POWER SUPPLY

Rated at 5V 500MA • Operates JBE A-D & D-A Converter, Z80 & 6502 Microcomputers, 8085 & 8088 Microcomputers.

80-160 ASSM. **$20.95**
Bare Board **$8.95** Kit **$16.95**

± 12 VOLT POWER SUPPLY

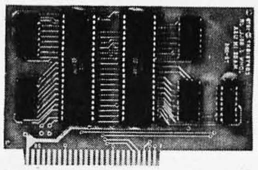
Rated at ± 12V 120MA • Can be used as a single 24V power supply • Ideally suited to OP-AMP experiments.

80-161 ASSM. **$22.95**
Bare Board **$8.95** Kit **$18.95**

ICS

6502	**$9.95**
6522	**$9.95**
Z80 CPU	**$9.95**
Z80 PIO	**$9.95**
2716	**$14.95**
2716 Programmed	**$19.95**

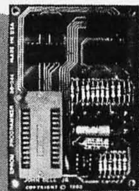
6522 APPLE II INTERFACE



• Interfaces printers, synthesizers, keyboards, JBE A-D & D-A Converter & Solid State Switches • Has handshaking logic, two 6522 VIAs & a 74LS05 for timing • Inputs & outputs are TTL compatible.

79-295 ASSM. **$69.95**
Bare Board **$39.95** Kit **$59.95**

2716 EPROM PROGRAMMER



JBE 2716 EPROM Programmer was designed to program 5V 2716 EPROMS • It can also read 2716s. It interfaces to the Apple II using JBE Parallel I/O Card & four ribbon cable connectors • An LED indicates when power is being applied to the EPROM • A textool zero insertion force socket is used for the EPROM • Comes with complete doc. for writing and reading in the Apple II or Apple II+ • Cables available separately.

80-244 ASSM. **$49.95**
Bare Board **$24.95** Kit **$39.95**
2 Ft. Ribbon Cable **$ 4.25**

BARE BOARDS

APPLE II EXTENDER BOARD

3½" x 2½". Price includes 50 pin Connector.

80-143 **$12.95**

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State-of-the-art system using an 8085, 8156 & either an 8355 or 8755 • Instruction set 100% upward compatible with 8080A.

Bare Board **$24.95**

8088 5 CHIP SYSTEM

An 8086 family microcomputer system using an 8088 CPU, 8284, 8155, 8755A & an 8185.

Bare Board **$29.95**

CRT CONTROLLER

This intelligent CRT Controller uses an 8085A CPU & an 8275 Integrated CRT Controller. It features: • 25 lines (80 Char./line) • 5x7 dot matrix • Upper & lower case • two 2716s (controller & char. generator) • serial interface RS232 & TTL • baud rates of 110, 150, 300, 600, 1200, 2400, 4800 & 9600 • keyboard scanning system • unencoded keyboard is req'd • uses +5V & ±12V power supplies • Doc. includes program listing & composite video circuit.

Bare Board only (Doc. incl.) **$39.95**
Programmed 2716s each **$19.95**

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What's New?

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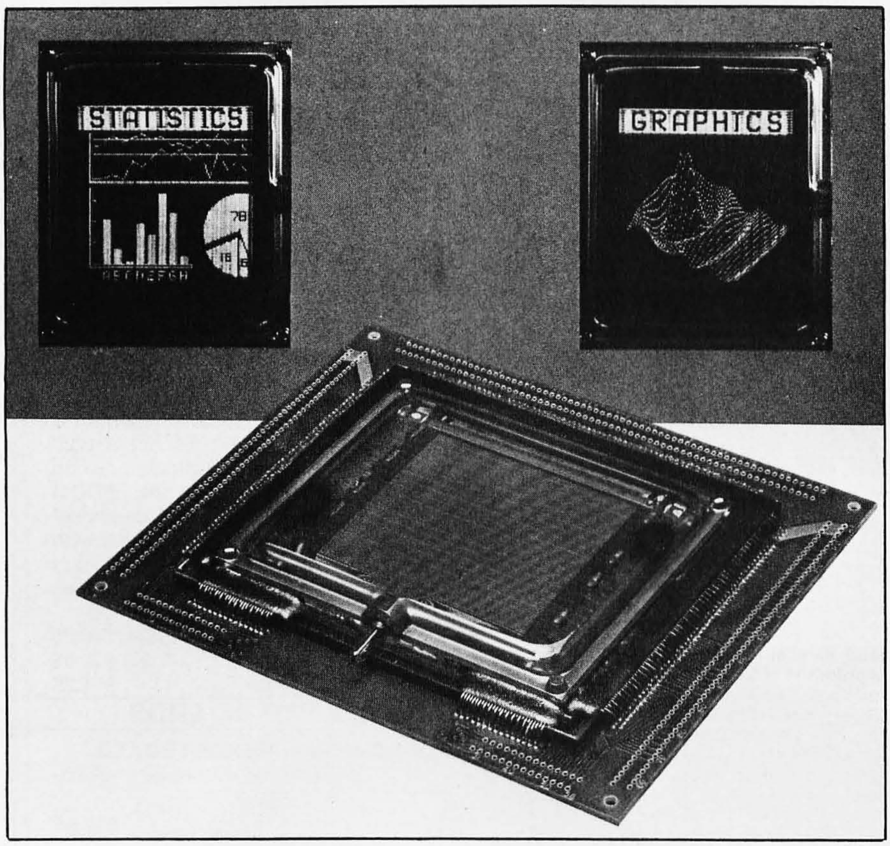


Compact Fluorescent Display Panel

The itron square-format DM128X128C 128 by 128 dot matrix display panel is slightly over 76.6 by 76.55 mm square (3 inches) and only 20 mm (0.8 inch) thick. It is capable of displaying special symbols, geometric patterns, graphics, block and cursive alphanumerics, continuously scrolling images, and lighted areas. Each dot is individually addressable, and ascenders and descenders, script lettering, linear graphics, and charts can be produced. For more information, contact Noritake Electronics Inc, 22410 Hawthorne Blvd, Torrance CA 90505, (213) 373-6704.

Circle 544 on inquiry card.

Where Do New Products Items Come From?

The information printed in the new products pages of BYTE is obtained from "new product" or "press release" copy sent by the promoters of new products. If in our judgment the information might be of interest to the personal computing experimenters and homebrewers who read BYTE, we print it in some form. We openly solicit releases and photos from manufacturers and suppliers to this marketplace. The information is printed more or less as a first-in first-out queue, subject to occasional priority modifications. While we would not knowingly print untrue or inaccurate data, or data from unreliable companies, our capacity to evaluate the products and companies appearing in the "What's New?" feature is necessarily limited. We therefore cannot be responsible for product quality or company performance.

Piggybacked Prototyping Boards

Circbords are perforated prototyping boards that can add 24 square inches of working area and 20 to 60 DIP (dual-inline package) positions when mounted on spacers, piggyback-style, on edge connector boards. Circbords can also be installed using card guides or in aluminum extrusions.

The Model 8001 is designed for solder connections. It holds up to twenty 16-pin integrated circuits. The Model 8002, for wrapped wire, can hold up to thirty-five 16-pin DIPs. On the 8003 model, up to sixty 16-pin DIPs, or any combination of devices, can be attached using solder or wire-wrap. Each Circbord costs $9.95. Contact Vector Electronic Company, 12460 Gladstone Ave, Sylmar CA 91342, (213) 365-9661.

Circle 545 on inquiry card.

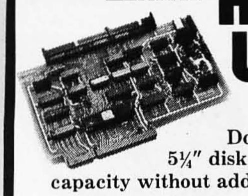
16 K-Byte ROM from OKI

OKI Semiconductor Inc has introduced an NMOS (n-type metal-oxide semiconductor), 128 K-bit ROM (read-only memory). The MSM-38128 is organized as 16 K bytes by 8 bits. It has a 450 ns maximum access time, operates off a single +5 V supply, and features a 120 mA supply current in the operating mode and 20 mA current in standby. Compatible with the 128 K-bit 2364 ROM from Intel, the MSM 38128 features power-down state and is nonclocked. All inputs and outputs are TTL (transistor-transistor logic) compatible.

For information, contact the the company at 1333 Lawrence Expy, Suite 401, Santa Clara CA 95051, (408) 984-4842.

Circle 546 on inquiry card.

ZENITH/Heath Users



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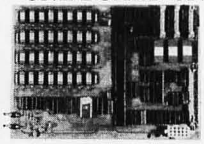

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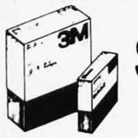

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WANTED:

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Westico is a publisher and distributor of professional software for microcomputers. If you have a new program ready for distribution or want your existing programs to reach a larger market, contact:

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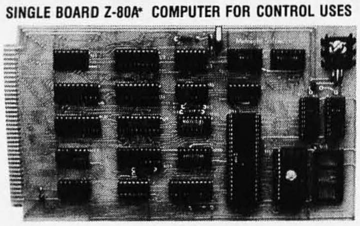

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In this mode your system acts as a terminal. Can send to or receive from a timesharing system. When receiving data from a remote system, received data is buffered to your maximum memory, then can be saved as a disk file.

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Communicate on-line with another computer similarly equipped. Both ends can type messages that appear simultaneously on both screens.

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Can display both local and remote directories.

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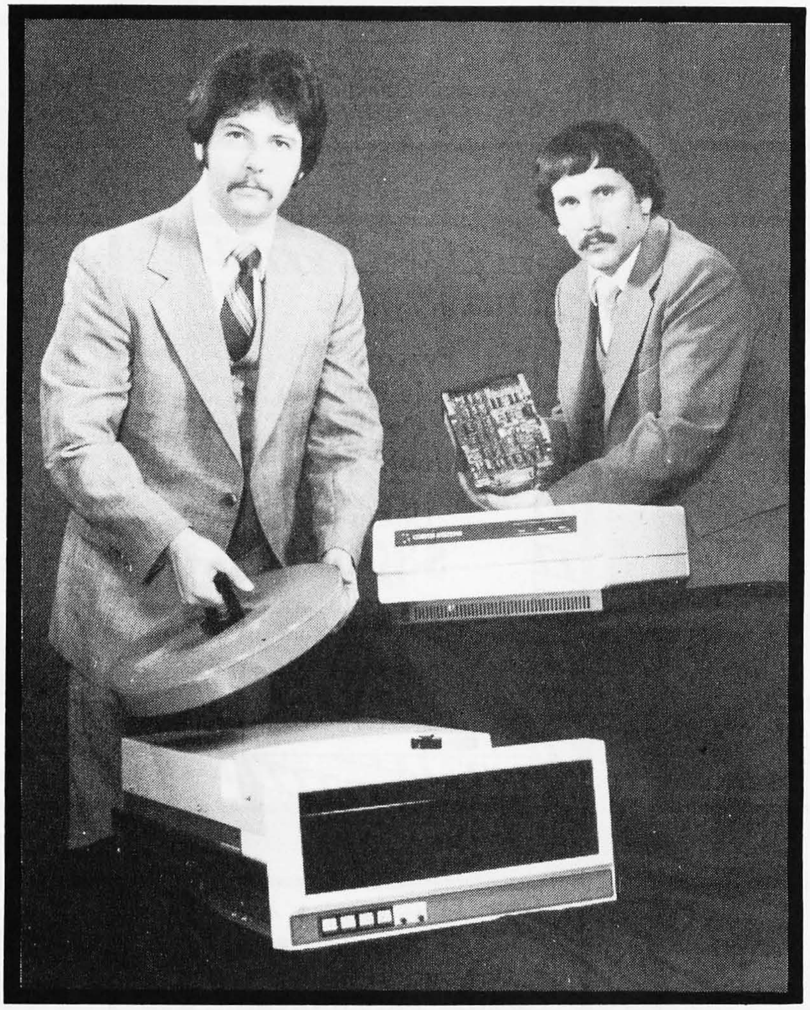
THE CAMEO CONNECTION

The Cameo 10 Million Character Disk Drive Subsystem (pictured in foreground) Is A 5 Megabyte Fixed, 5 Megabyte Removable Cartridge-Type Disk Drive. Advantages To This Unit Are Ease of Backup For Data and Program Files and Low Cost. By Attaching A Multiplexor Unit Several Model II's Can Be Attached To The Cameo Disk Drive. For Further Pricing, Availability, and Operating Systems Options, Call or Write to American Small Business Computers and ask for the CAMEO CONNECTION.



THE CORVUS CONNECTION

The Corvus Disk Drive Subsystem (center of picture) Is Available in 5, 10, and 20 Million Character Capacities. The Corvus System Is The Ultimate In The Sealed "Winchester, All-Fixed" Type Drive. The Corvus Is Designed To Operate In The Harshest Environments Such As Factories, Oil Rigs, Etc. Backup Of Data Is Accomplished Via Optional MIRROR Backup Device Whereby Data Is Written Onto A Standard Video Tape Recorder. A Great Number of Model II's May Be Attached To The Corvus Via An Optional CONSTELLATION Multiplexor. For Further Pricing, Availability, and Operating Systems, Call Or Write to American Small Business Computers and Ask for the CORVUS CONNECTION.

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7430N	.25
7442N	.58
7445N	.82
7447N	.63
7448N	.77
7450N	.25
7474N	.35
7475N	.49
7485N	.88
7489N	1.70
7490N	.43
7492N	.43
7493N	.43
7495N	.69
74100N	1.35
74107N	.35
74121N	.34
74123N	.59
74125N	.45
74145N	.77
74150N	1.20
74151N	.69
74154N	1.25
74157N	.69
74161N	.87
74162N	.85
74163N	.87
74174N	.96
74175N	.85
74190N	1.15
74192N	.87
74193N	.85
74221N	1.25
74298N	1.65
74365N	.75
74366N	.75
74367N	.75

74LS00 TTL	
74LS00N	.29
74LS02N	.29
74LS04N	.35
74LS05N	.25
74LS08N	.35
74LS10N	.35
74LS13N	.55
74LS14N	1.00
74LS20N	.35
74LS22N	.35
74LS28N	.35
74LS30N	.35
74LS33N	.60
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74LS74N	.45
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LM309K	1.25
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LM317T	1.65
LM317K	3.75
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LM320K-5	1.35
LM320K-12	1.35
LM320K-15	1.35
LM320T-5	.95
LM320T-8	.95
LM320T-12	.95
LM320T-15	.95
LM323K-5	5.95
LM324N	1.00
LM339N	1.00
LM340K-5	1.35
LM340K-8	1.35
LM340K-12	1.35
LM340K-15	1.35
LM340K-24	1.35
LM340T-5	.85
LM340T-8	.85
LM340T-12	.85
LM340T-15	.85
LM340T-18	.85
LM340T-24	.85
LM350	5.50
LM377	2.95
LM379	5.00
LM380N	1.00
LM381	1.60
LM382	1.60
LM709H	.59
LM723H/N	.50
LM733N	.85
LM741CH	.35
LM741N	.38
LM747H/N	.75
LM748N	.50
LM1303N	1.75
LM1304	1.10
LM1305	1.27
LM1307	2.00
LM1310	2.75
LM1458	.55
LM1812	7.50
LM1889	3.00
LM2111	1.75
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LM3900N	.60
LM3905	1.75
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NE555V	.39
NE556A	.85
NE565A	1.00
NE566V	1.50
NE567V	1.00
NE570B	4.75
78L05	.60
78L08	.60
78M05	.85
75108	1.75
75491CN	.50
75492CN	.55
75494CN	.89

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8700CJ	13.95
8701CN	22.00
8750CJ	13.95
LD130	9.95
9400CJV/F	7.40
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CD4007	.35
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CD4009	.45
CD4010	.45
CD4011	.35
CD4012	.28
CD4013	.47
CD4014	1.25
CD4015	1.00
CD4016	.55
CD4017	1.05
CD4018	.94
CD4019	.45
CD4020	1.02
CD4021	1.35
CD4022	1.10
CD4023	.28
CD4024	.75
CD4025	.28
CD4026	2.50
CD4027	.66
CD4028	.85
CD4029	1.35
CD4030	.45
CD4035	1.00
CD4040	1.35
CD4042	.85
CD4043	.85
CD4044	.85
CD4046	1.67
CD4049	.45
CD4050	.60
CD4051	1.13
CD4060	1.42
CD4066	.71
CD4068	.40
CD4069	.40
CD4070	.50
CD4071	.45
CD4072	.45
CD4073	.45
CD4075	.45
CD4076	1.45
CD4078	.40
CD4081	.35
CD4082	.35
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CD4490	5.50
CD4507	1.00
CD4508	2.85
CD4510	1.00
CD4511	.94
CD4515	2.52
CD4516	1.10
CD4518	1.50
CD4520	1.02
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CD4583	2.35
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74C14	.89
74C20	.35
74C30	.35
74C48	1.95
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74C76	1.25
74C90	1.25
74C93	1.25
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74C914	1.95
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74C923	5.50
74C925	7.50
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8096	.65
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8T13	3.00
8T20	5.50
8T23	3.10
8T24	3.50
8T25	3.20
8T26	1.69
8T28	2.75
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2102AN-2L	1.65
2104A-4	4.95
2107B-4	3.75
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MM57100	4.50
GIAY38500-1	9.95
MCM66751A	9.95
9368	3.50
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14	.14	24	.35
16	.16	28	.42
18	.27	36	.58
20	.29	40	.57

2 level 14 pin ww .20

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PIN		PIN	
14	.55	24	.93
16	.57	28	1.00
18	.67	40	1.59

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DL747/750	CA/CC	.600	1.95
FND359	CC	.357	.70
FND500/507	CC/CA	.500	1.35
FND503/510	CC/CA	.500	.90
FND800/807	CC/CA	.800	2.20
3 digit Bubble			.60
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7520 Clairex photocells			.39
TIL311 Hex			9.50
MAN3640	CC	.30	1.10
MAN4610	CA	.40	1.20
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MAN4740	CC	.40	1.20
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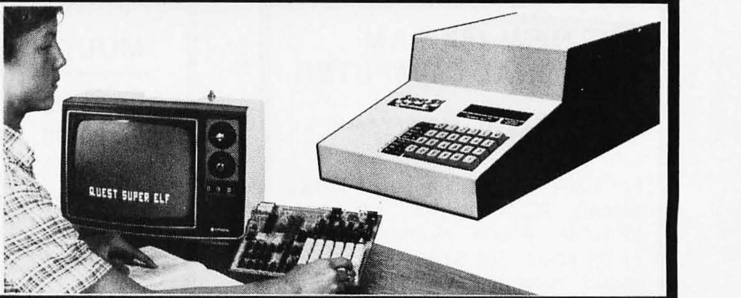

RCA Cosmac 1802 Super Elf Computer $106.95

Compare features before you decide to buy any other computer. There is no other computer on the market today that has all the desirable benefits of the **Super Elf** for so little money. The Super Elf is a small single board computer that does many **big** things. It is an excellent computer for training and for learning programming with its machine language and yet it is easily **expanded** with **additional memory, Full Basic, ASCII Keyboards, video character generation, etc.**

Before you buy another small computer, see if it includes the following features: ROM monitor; State and Mode displays; Single step; Optional address displays; Power Supply; Audio Amplifier and Speaker; Fully socketed for all IC's; Real cost of in warranty repairs; Full documentation.

The **Super Elf** includes a **ROM** monitor for program loading, editing and execution with **SINGLE STEP for program debugging** which is not included in others at the same price. With **SINGLE STEP** you can see the microprocessor chip operating with the **unique Quest** address and data bus displays **before, during** and **after** executing instructions. Also, CPU mode and instruction cycle are decoded and displayed on 8 LED indicators.

An RCA 1861 **video graphics** chip allows you to connect to your own TV with an inexpensive video modulator to do graphics and games. There is a **speaker system** included for writing your own music or using many music programs already written. The speaker amplifier may also be used to drive relays for control purposes.

A 24 key **HEX keyboard** includes 16 HEX keys plus **load, reset, run, wait, input, memory protect, monitor select** and **single step**. Large, on board displays provide output and optional **high and low address**. There is a 44 pin standard connector slot for PC cards and a 50 pin connector slot for the Quest Super Expansion Board. Power supply and sockets for **all** IC's are included in the price plus a detailed 127 pg. instruction manual which now includes over 40 pgs. of software info. including a series of lessons to help get you started and a music program and graphics target game. Many schools and universities are using the Super Elf as a course of study. OEM's use it for training and R&D.

Remember, other computers only offer Super Elf features at additional cost or not at all. **Compare before you buy. Super Elf Kit $106.95, High address option $8.95, Low address option $9.95. Custom Cabinet** with drilled and labelled plexiglass front panel **$24.95.** All metal Expansion Cabinet, painted and silk screened, with room for 5 S-100 boards and power supply **$57.00. NiCad Battery Memory Saver Kit $6.95.** All kits and options also completely assembled and tested.

Questdata, a software publication for 1802 computer users is available by subscription for $12.00 per 12 issues. Single issues $1.50. Issues 1-12 bound $16.50.

Free 14 page brochure.
of complete Super Elf system.

Moews Video Graphics **$3.50.** Games and Music **$3.00,** Chip 8 Interpreter **$5.50.**

Super Expansion Board with Cassette Interface $89.95

This is truly an astounding value! This board has been designed to allow **you** to decide how you want it optioned. **The Super Expansion Board comes with 4K of low power RAM** fully addressable anywhere in 64K with built-in memory protect and a **cassette interface.** Provisions have been made for all other options on the same board and it fits neatly into the hardwood cabinet alongside the **Super Elf.** The board includes slots for up to 6K of **EPROM** (2708, 2758, 2716 or TI 2716) and is **fully socketed.** EPROM can be used for the monitor and Tiny Basic or other purposes.

A 1K Super ROM Monitor $19.95 is available as an on board option in 2708 EPROM which has been preprogrammed with a program loader/editor and error checking multi file cassette read/write software, (relocatable cassette file) another exclusive from Quest. It includes register save and readout, block move capability and video graphics driver with blinking cursor. Break points can be used with the register save feature to isolate program bugs quickly, then follow with single step. If you have the **Super Expansion Board** and **Super Monitor** the monitor is up and running at the push of a button.

Other on board options include **Parallel Input and Output Ports** with **full handshake.** They allow easy connection of an ASCII keyboard to the input port. **RS 232 and 20 ma Current Loop** for teletype or other device are on board and if you need more memory there are two **S-100** slots for static RAM or video boards. Also a 1K Super Monitor version 2 with video driver for full capability display with Tiny Basic and a video interface board. **Parallel I/O Ports $9.85, RS 232 $4.50, TTY 20 ma I/F $1.95, S-100 $4.50. A 50 pin connector set** with ribbon cable is available at $15.25 for easy connection between the **Super Elf** and the **Super Expansion Board.**

Power Supply Kit for the complete system (see Multi-volt Power Supply).

Quest Super Basic V5.0

A new enhanced version of **Super Basic** now available. Quest was the first company worldwide to ship a full size Basic for 1802 Systems. A complete function **Super Basic** by **Ron Cenker** including floating point capability with scientific notation (number range $\pm .17E^{38}$), 32 bit integer ± 2 billion; multi dim arrays, string arrays; string manipulation; cassette I/O; save and load, basic, data and machine language programs; and over 75 statements, functions and operations.

New improved faster version including **renumber** and essentially **unlimited variables.** Also, an exclusive user expandable command library.

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Super Basic on Cassette $55.00.

Elf II Adapter Kit $24.95

Plugs into Elf II providing Super Elf 44 and 50 pin plus S-100 bus expansion. (With *Super Expansion).* High and low address displays, state and mode LED's optional **$18.00.**

Super Color S-100 Video Kit $129.95

Expandable to 256 x 192 high resolution color graphics. 6847 with all display modes computer controlled. Memory mapped. 1K RAM expandable to 6K. S-100 bus 1802, 8080, 8085, Z80 etc.

Dealers: Send for excellent pricing/margin program.

Editor Assembler	**$25.00**
(Requires minimum of 4K for E/A plus user source)	
1802 Tiny Basic Source listing	**$19.00**
Super Monitor V2.0/2.1 Source Listing	**$20.00**

PROM Eraser

assembled. 25 PROM capacity **$37.50** (with timer **$69.50**). 6 PROM capacity OSHA/UL version **$78.50** (with timer **$108.50**).

Z80 Microcomputer

16 bit I/O, 2 MHz clock, 2K RAM, ROM Breadboard space. Excellent for control. Bare Board **$28.50.** Full Kit **$99.00.** Monitor **$20.00.** Power Supply Kit **$35.00. Tiny Basic $30.00**

S-100 Computer Boards

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32K Static Godbout Econo XX-32 Kit	537.00
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Video Interface Kit	**$161.00**
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81 IC Update Master Manual $79.95

Comp. IC data selector, 2 vol. master reference guide. Over 51,000 cross references. Free update service through 1981. Domestic postage $4.75.

Modem Kit $60.00

State of the art, orig., answer. No tuning necessary. 103 compatible 300 baud. Inexpensive acoustic coupler plans included. Bd. Only $17.00. Article in June *Radio Electronics.*

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32 x 16 alpha/numerics and graphics; up to 8 colors with 6847 chip; 1K RAM at E000. Plugs into Super Elf 44 pin bus. No high res. graphics. On board RF Modulator Kit **$4.95**

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Rockwell AIM 65 Computer

6502 based single board with full ASCII keyboard and 20 column thermal printer. 20 char. alphanumeric display, ROM monitor, fully expandable. **$405.00.** 4K version **$450.00.** 4K Assembler **$85.00,** 8K Basic Interpreter **$100.00.**

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Type-N-Talk by Votrax

Text to speech synthesizer with unlimited vocabulary, built-in text to speech algorithm, 70 to 100 bits per second speech synthesizer, RS232C interface $345.00.

1802 16K Dynamic RAM Kit $149.00

Expandable to 64K. Hidden refresh w/clocks up to 4 MHz w/no wait states. Addl. 16K RAM **$25.00**

Tiny Basic Extended on Cassette	**$15.00**
(Added commands include Stringy, Array, Cassette I/O etc.) S-100 4-slot expansion	**$ 9.95**
Super Monitor VI.I Source Listing	**$15.00**

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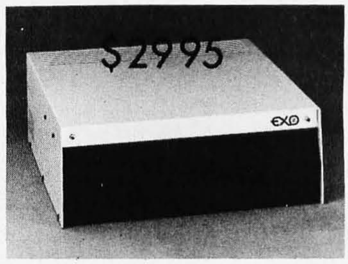

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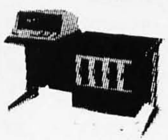

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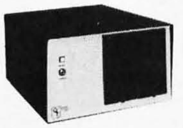

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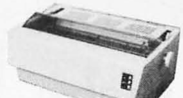

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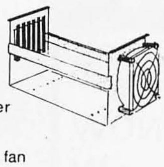

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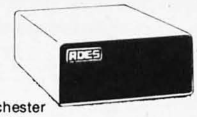

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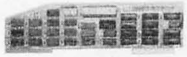

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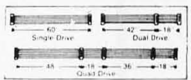

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SN7438N	24	SN74161N	.65
SN7440N	18	SN74163N	.85
SN7442N	45	SN74164N	.87
SN7443N	42	SN74165N	.55
SN7445N	64	SN74174N	.88
SN7451N	19	SN74175N	.79
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74LS00	.28	74LS158	.69
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74LS04	.28	74LS163	.98
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74LS126	.79	74LS367	.75
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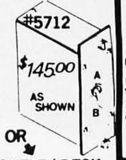

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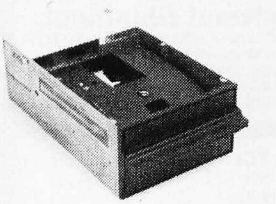

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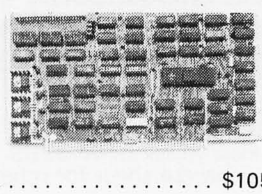

Tarbell single density kit	$195
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AMPEX DIALOGUE 30, 80		**$CALL**
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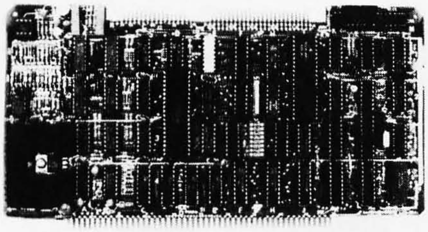

S-100 bus compatible • Reads and writes single or double density • Density is software selectable • Controls up to four 5-1/4" or 8", single or double-sided drives • Single or double-sided drives may be mixed in the same system • On-board Z-80A to assure reliable operation • EIA level serial printer interface on board, baud rates to 9600 (perfect for despooling operations) • Uses IBM standard formats • Designed to meet IEEE signal disciplines • Works with 8080, 8085, and Z-80 CPU's.

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JADE The Big Z ™
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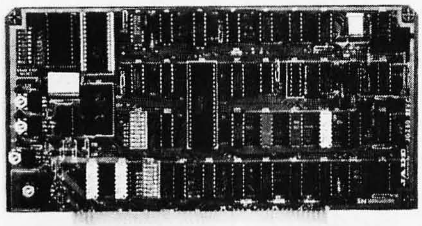

S-100 bus compatible • Switch selectable 2 or 4 MHz operation • Serial I/O port • Accomodates a 2708, 2716, or 2732 EPROM in shadow mode allowing full use of 64K RAM • MWRITE signal is generated automatically if used without front panel • On-board 8251 USART controls serial port at baud rates from 75 to 9600 baud • Switch selectable 1K, 2K, or 4K boundary fully buffered • Power-on jump to EPROM

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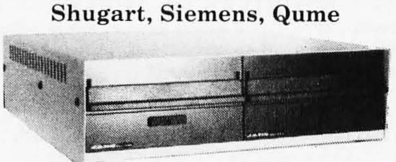
2114L *4 MHz*	3.35	2.99	2.75	2.49
2708 *2 MHz*	4.90	3.90	3.45	2.90
2532 *2 MHz*	24.90	19.90	15.90	12.90
2716 *2 MHz*	8.90	7.45	6.45	5.75
2716 *4 MHz*	19.90	15.45	13.45	11.75
2732 *2 MHz*	24.90	19.90	15.90	12.90
2732 *4 MHz*	39.90	29.90	24.90	19.90
2758 *2 MHz*	6.90	6.25	5.50	4.50
4116 *200 ns*	3.25	2.99	2.49	1.99
4164 *200 ns*	28.90	24.90	22.90	19.90

JADE Disk Sub-Systems
Shugart, Siemens, Qume



Handsome metal cabinet with proportionally balanced air flow system • Rugged dual drive power supply • Power cable kit • Power switch, line cord, fuse holder, cooling fan • Never-Mar rubber feet • All necessary hardware to mount 2-8" disk drives, power supply, and fan • Does not include signal cable

Dual 8" Subassembly Cabinet

END-000420	*Bare cabinet*	$59.95
END-000421	*Cabinet kit*	$225.00
END-000431	*A & T*	$359.95

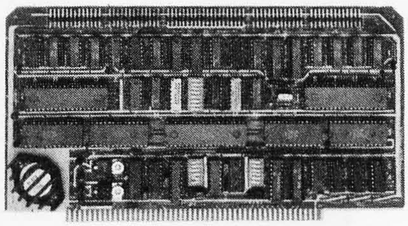
8" Disk Drive Subsystems
Single Sided, Double Density

END-000423	*Kit w/2 FD100-8Ds*	$975.00
END-000424	*A & T w/2 FD100-8Ds*	$1175.00
END-000433	*Kit w/2 SA-801Rs*	$999.95
END-000434	*A & T w/2 SA-801Rs*	$1195.00

8" Disk Drive Subsystems
Double Sided, Double Density

END-000426	*Kit w/2 DT-8s*	$1475.00
END-000427	*A & T w/2 DT-8s*	$1675.00
END-000436	*Kit w/2 SA-851Rs*	$1495.00
END-000437	*A & T w/2 SA-851Rs*	$1695.00

JADE S.P.I.C.
Our "SPICy" New I/O Board



New, from JADE, one of the most advanced, technologically sophisticated Serial/Parallel Interrupt Controller systems in the world. On a single IEEE S-100 standard board, JADE has packed two bi-directional parallel ports with full handshaking, four serial channels (asynchronous, IBM-compatible bi-synch, synchronous, HDLC/SDLC) with full and complete modem control lines, and 16 counter-timer channels.

Utilizing the highly advanced Zilog peripheral chips, (Z-80 SIO, PIO & CTCs), the SPIC board is fully programmable to serve as the foundation for a multi-user multi-tasking system. Each of the seven Z-80 peripheral chips can generate its own interrupt vector, with daisy-chain priority levels. Each counter-timer channel can be programmed to monitor an interrupt vector line on the S-100 bus. Each SIO channel can be driven independently with separate Tx/Rx clocks so your peripherals can have varied baud rates from 110 to 76,800 baud.

IOI-1045B	*Bare Board*	$49.95
IOI-1045K	*2 CTC's, 1 SIO, 1 PIO*	$179.95
IOI-1045A	*A & T*	$239.95
IOI-1046K	*4 CTC's, 2 SIO's, 1 PIO*	$219.95
IOI-1046A	*A & T*	$299.95

Build It Yourself and Save $1850

Complete S-100 Micro-Computer Kit

4 Mhz Big Z CPU, 64K Memory Bank, Double-D disk controller, 12 slot mainframe, dual disk sub-assembly with 2 double density 8" disk drives & power supply, ADDS Viewpoint terminal, CP/M 2.2, boot PROM, system monitor, & all necessary cables and manuals - ***PLUS FREE Business Software Package.*** *Save over $1850.00* **$2795.00**

Jade Business Software

Now, for the first time, at an amazingly low price, CP/M and SDOS users can get an affordable business software package. Just look at these programs! All come complete with basic code (written to run under CBASIC Ⅱ), for easy customizing and modification. All software is self-documenting. The package price includes a word-processing system. When printed on the system's printer, all files with the extension xxxTOT. constitute a complete manual. No manuals are supplied with the package other than as they appear on the disks. All software is supplied on 8" premium quality JADE Diskettes. Software sold as is. (Sorry, but at these low prices we can not offer our usual *friendly* support and handholding.)

Includes; General Ledger, Payroll, Invoicing, Inventory Control, Accounts Recievable, Cash Disbursements, Fixed Assets, Cash Receipts, & Mailing List Management.

Special Package Price ***$249.95***

Circle 178 on inquiry card.

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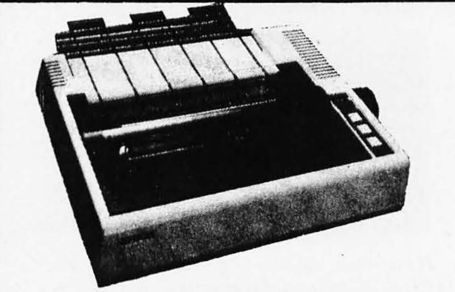
Printers



BEST BUY in PRINTERS - Epson

MX-70 *132 column, 80 CPS, 5 x 7 dot matrix, adjustable tractor feed, & graphics*
PRM-27070 *List $459* **$399.95**

MX-80 *132 column, 80 CPS, bi-directional/logic seeking printing, 9 x 9 dot matrix, adjustable tractor feed, & 64 graphics characters*
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PRA-27084 *Serial interface* **$69.95**
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PRA-27082 *Apple cable* **$22.95**
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65 cps, bi-directional, letter quality printer with deluxe tractor mechanism, both parallel and serial interfaces on-board, 16K buffer, ribbon, print thimble, graphics, micro-space justification, data cable, and self test/diagnostic ROM.
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Accessories for TRS-80

DISK DRIVES for TRS-80

23% more storage, 8 times faster, 40 track with free patch, 120 day warranty.
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8" DISK DRIVES for MODEL II

2 double density drives with cabinet, power supply, & cables
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WCA-5036A *Cable (required)* **$29.95**

16K Atari ... $359.95

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Complete personal computer with high resolution color graphics, built-in RF modulator, 4 controller ports, internal speaker, 16K RAM & 8K ROM
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IOX-5050A *850 interface* **$199.95**
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16K MEMORY UPGRADE

Add 16K of RAM to your TRS-80, Apple, or Exidy in just minutes. We've sold thousands of these 16K RAM upgrades which include the appropriate memory chips (as specified by the manufacturer), all necessary jumper blocks, fool-proof instructions, and our 1 year guarantee.
MEX-16100K *TRS-80 kit* **$25.00**
MEX-16101K *Apple kit* **$25.00**
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16K RAM Card - Microsoft

(There is life after 48K)
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Two computers in one, Z-80 & 6502, more than doubles the power & potential of your Apple, includes Z-80 CPU card, CP/M 2.2, & BASIC-80*
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Controller, DOS, two 8" double densisty drives, cabinet, power supply, & cables
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PRINTER INTERFACE - C.C.S.

Centronics type I/O card w/ firmware
IOI-2041A *A & T* **$99.95**

AIO, ASIO, APIO - S.S.M.

Parallel & serial interface for your Apple (see Byte pg 11)
IOI-2050K *Par & Ser kit* **$139.95**
IOI-2050A *Par & Ser A & T* **$169.95**
IOI-2052K *Serial kit* **$89.95**
IOI-2052A *Serial A & T* **$99.95**
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IOI-2054A *Parallel A & T* **$89.95**

A488 - S.S.M.

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CPS MULTICARD - Mtn. Computer

Three cards in one! Real time clock/calendar, serial interface, & parallel interface - all on one card.
IOX-2300A *A & T* **$199.95**

Apple-CAT - Novation

Software selectable 1200 or 300 baud, direct connect, auto-answer/auto-dial, auxiliary 3-wire RS232C serial port for printer.
IOM-5232A *Save $50.00!!!* **$339.95**

Single Board Computers

AIM-65 - Rockwell

6502 computer with alphanumeric display, printer, & keyboard, and complete instructional manuals
CPK-50165 *1K AIM* **$424.95**
CPK-50465 *4K AIM* **$499.95**
SFK-74600008E *8K BASIC ROM* ... **$99.95**
SFK-64600004E *4K assembler ROM* **$84.95**
PSX-030A *Power supply* **$64.95**
ENX-000002 *Enclosure* **$54.95**
4K AIM, 8K BASIC, power supply, & enclosure
Special package price **$675.00**

Z-80* STARTER KIT - SD Systems

Complete Z-80 computer with RAM, ROM, I/O, display, keyboard, manual, and kluge area.*
CPS-30010K *Kit* **$369.95**
CPS-30010A *A & T* **$459.95**

SYM-1 - Synertek Systems

Single board computer with 1K of RAM, 4K of ROM, key-pad, LED display, 20ma & cassette interface on board.
CPK-50020A *A & T* **$249.95**

Video Terminals

VIEWPIONT - ADDS

Detachable keyboard, serial RS232C interface, baud rates from 110 to 19,200, auxiliary serial output port, 24 x 80 display, tiltable screen, international character set
VDT-501210 *Sale Priced* **$639.95**

TELEVIDEO 950

Detachable keyboard, split screen with line lock, etched CRT, programmable function keys, on-screen status line, buffered auxiliary port, 14 x 10 dot matrix, self test, serviced nation-wide by General Electric
VDT-901250 *List $1195.00* **$995.00**

Video Monitors

Leedex / Amdek

Reasonably priced video monitors
VDM-801210 *Video 100 12" B&W* .. **$139.95**
VDM-801230 *Video 100-80 12" B& W* **$179.95**
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13" COLOR MONITOR - Zenith

The hi res color you've been promising yourself
VDC-201301 .... **$449.00**

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VDM-651200 *12" monitor* **$269.95**

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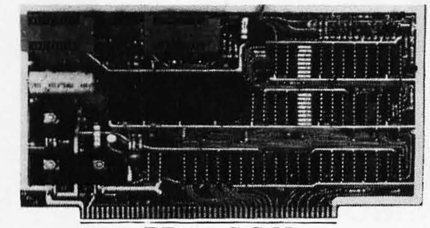
Circle 179 on inquiry card

Faster Service.

S-100 PROM Boards



PB-1 - S.S.M.
2708, 2716 EPROM board with built-in programmer
MEM-99510K *Kit* $154.95
MEM-99510A *A & T* $219.95

PROM-100 - SD Systems
2708, 2716, 2732, 2758, & 2516 EPROM programmer
MEM-99520K *Kit* $219.95
MEM-99520A *Jade A & T* $269.95

EPROM BOARD - Jade
16K or 32K uses 2708's or 2716's, 1K boundary
MEM-16230K *Kit* $79.95
MEM-16230A *A & T* $119.95

S-100 Video

VB-3 - S.S.M.
80 characters x 24 lines expandable to 80 x 48 for a full page of text, upper & lower case, 256 user defined symbols, 160 x 192 graphics matrix, memory mapped, has key board input.
IOV-1095K *4 MHz kit* $349.95
IOV-1095A *4 MHz A & T* $439.95
IOV-1096K *80 x 48 upgrade* $39.95

VDB-8024 - SD Systems
80 x 24 I/O mapped video board with keyboard I/O, and on-board Z-80A.*
IOV-1020K *Kit* $399.95
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VIDEO BOARD - S.S.M.
64 characters x 16 lines, 128 x 48 matrix for graphics, full upper/lower case ASCII character set, numbers, symbols, and greek letters, normal/reverse/blinking video, S-100.
IOV-1051K *Kit* $149.95
IOV-1051A *A & T* $219.95
IOV-1051B *Bare board* $34.95

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ISO-BUS - Jade
Silent, simple, and on sale - a better motherboard
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MBS-061B *Bare board* $19.95
MBS-061K *Kit* $39.95
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MBS-121B *Bare board* $29.95
MBS-121K *Kit* $69.95
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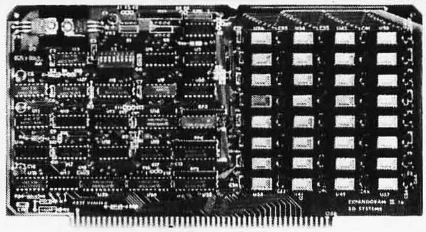
MBS-181K *Kit* $99.95
MBS-181A *A & T* $139.95

Mainframes

MAINFRAME - Cal Comp Sys
12 slot S-100 mainframe with 20 amp power supply
ENC-112105 *Kit* $379.95
ENC-112106 *A & T* $409.95

DISK MAINFRAME - N.P.C.
Holds 2 8" drives and a 12 slot S-100 system. Attractive metal cabinet with 12 slot motherboard & card cage, power supply, dual fans, lighted switch, and other professional features
ENS-112325 *with 25 amp p.s.* $699.95

S-100 Memory



EXPANDORAM II - S D Systems
4 MHz RAM board expandable from 16K to 64K
MEM-16630K *16K kit* $275.95
MEM-32631K *32K kit* $295.95
MEM-48632K *48K kit* $315.95
MEM-64633K *64K kit* $335.95
Assembled & tested .... add $50.00

64K RAM - Calif Computer Sys
4 MHz bank port / bank byte selectable, extended addressing, 16K bank selectable, PHANTOM line allows memory overlay, 8080 / Z-80 / front panel compatible.
MEM-64565A *A & T* $575.00

32K STATIC RAM - Jade
2 or 4 MHz expandable static RAM board uses 2114L's
MEM-16151K *16K 4 MHz kit* $169.95
MEM-32151K *32K 4 MHz kit* $299.95
Assembled & tested .... add $50.00

16K STATIC RAM - Mem Merchant
4 MHz 16K static RAM board, IEEE S-100, bank selectable, Phantom capability, addressable in 4K blocks, "disable-able" in 1K segments, extended addressing, low power
MEM-16171A *A & T* $174.95

S-100 Disk Controller

DOUBLE DENSITY - Cal Comp Sys
5¼" and 8" disk controller, single or double density, with on-board boot loader ROM, and free CP/M 2.2 and manual set.*
IOD-1300A *A & T* $369.95

VERSAFLOPPY II - SD Systems
New double density controller for both 8" & 5¼"
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Disk Drives

8" DISK DRIVES
Highly reliable double density floppy disk drives
Shugart 801R single sided, double density
MSF-10801R *SA-801R* $425.00
Special Sale Price .... **2 for $790.00**

Shugart 851R double sided, double density
MSF-10851R *SA-851R* $595.00
Special Sale Price .... **2 for $1150.00**

Siemens FDD100-8D2 single sided, double density
MSF-201120 .... $385.00
Special sale price .... **2 for $750.00**

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JADE DISK PACKAGE
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Special Package Price *Kit* $1395.00

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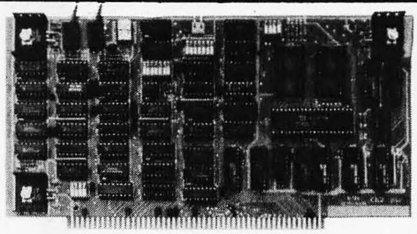
S-100 CPU



CB-2 Z-80 CPU - S.S.M.
2 or 4 MHz Z-80 CPU board with provision for up to 8K of ROM or 4K of RAM on board, extended addressing, IEEE S-100, front panel compatible.
CPU-30300K *Kit* $239.95
CPU-30300A *A & T* $299.95

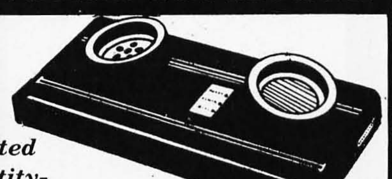
2810 Z-80* CPU - Cal Comp Sys
2/4 MHz Z-80A CPU with RS-232C serial I/O port and on-board MOSS 2.2 monitor PROM, front panel compatible.*
CPU-30400A *A & T* $269.95

SBC-200 - SD Systems
4 MHz Z-80 CPU with serial & parallel I/O ports, up to 8K of on-board PROM, software programmable baud rate generator, 1K of on-board RAM, Z-80 CTC.*
CPC-30200K *Kit* $339.95
CPC-30200A *Jade A & T* $399.95

S-100 I/O

I/O-4 - S.S.M.
2 serial I/O ports plus 2 parallel I/O ports
IOI-1010K *Kit* $179.95
IOI-1010A *A & T* $249.95
IOI-1010B *Bare board* $35.00

Novation Cat Modem



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IOM-5200A *List price $189.95* **$125.00**

D-CAT 300 baud, direct connect modem
IOM-5201A *Special sale price* **$169.95**

AUTO-CAT Auto answer/origiate, direct connect
IOM-5230A *Special sale price* **$239.95**

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16K Memory 8/$16.95

4116 300ns

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74LS08	.35	74LS170	1.75
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74LS22	.25	74LS194	1.00
74LS26	.35	74LS195	.95
74LS27	.35	74LS196	.85
74LS28	.35	74LS197	.85
74LS30	.25	74LS221	1.20
74LS32	.35	74LS240	1.85
74LS33	.55	74LS241	1.85
74LS37	.55	74LS242	1.85
74LS38	.35	74LS243	1.85
74LS40	.25	74LS244	1.75
74LS42	.55	74LS245	2.85
74LS47	.75	74LS247	.76
74LS48	.75	74LS248	1.25
74LS49	.75	74LS249	.99
74LS51	.25	74LS251	1.30
74LS54	.35	74LS253	.85
74LS55	.35	74LS257	.85
74LS63	1.25	74LS258	.85
74LS73	.40	74LS259	2.85
74LS74	.45	74LS260	.65
74LS75	.50	74LS266	.55
74LS76	.40	74LS273	1.65
74LS78	.50	74LS275	3.35
74LS83	.75	74LS279	.55
74LS85	1.15	74LS280	1.98
74LS86	.40	74LS283	1.00
74LS90	.65	74LS290	1.25
74LS91	.89	74LS293	1.85
74LS92	.70	74LS295	1.05
74LS93	.65	74LS298	1.20
74LS95	.85	74LS352	1.55
74LS96	.95	74LS353	1.55
74LS107	.40	74LS363	1.35
74LS109	.40	74LS365	.95
74LS112	.45	74LS366	.95
74LS113	.45	74LS367	.70
74LS114	.50	74LS368	.70
74LS122	.45	74LS373	1.85
74LS123	.95	74LS374	1.80
74LS124	2.99	74LS377	1.45
74LS125	.95	74LS378	1.18
74LS126	.85	74LS379	1.35
74LS132	.75	74LS385	1.90
74LS136	.55	74LS386	.65
74LS137	.99	74LS390	1.90
74LS138	.75	74LS393	1.90
74LS139	.75	74LS395	1.65
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74LS147	2.49	74LS447	.37
74LS148	1.35	74LS490	1.95
74LS151	.75	74LS668	1.69
74LS153	.75	74LS669	1.89
74LS154	2.35	74LS670	2.20
74LS155	1.15	74LS674	9.65
74LS156	.95	74LS682	3.20
74LS157	.75	74LS683	2.30
74LS158	.75	74LS684	2.40
74LS160	.90	74LS685	2.40
74LS161	.95	74LS688	2.40
74LS162	.95	74LS689	2.40

7400 SERIES

7400	.19	74128	.55
7401	.19	74132	.45
7402	.19	74136	.50
7403	.19	74141	.65
7404	.19	74142	2.95
7405	.22	74143	2.95
7406	.22	74144	2.95
7407	.22	74145	.60
7408	.24	74147	1.75
7409	.19	74148	1.20
7410	.19	74150	1.35
7411	.25	74151	.65
7412	.30	74152	.65
7413	.35	74153	.55
7414	.55	74154	1.40
7416	.25	74155	.75
7417	.25	74156	.65
7420	.19	74157	.55
7421	.35	74159	1.65
7422	.29	74160	.85
7423	.29	74161	.70
7425	.29	74162	.85
7426	.29	74163	.85
7427	.29	74164	.85
7428	.45	74165	.85
7430	.19	74166	1.00
7432	.29	74167	1.95
7433	.45	74170	1.65
7437	.29	74172	5.95
7438	.29	74173	.75
7440	.19	74174	.89
7442	.49	74175	.89
7443	.65	74176	.89
7444	.69	74177	.75
7445	.69	74178	1.15
7446	.59	74179	1.75
7447	.69	74180	.75
7448	.69	74181	2.25
7450	.19	74182	.75
7451	.23	74184	2.00
7453	.23	74185	2.00
7454	.23	74186	18.50
7460	.23	74190	1.15
7464	.39	74191	1.15
7465	.39	74192	.79
7470	.35	74193	.79
7472	.29	74194	.85
7473	.34	74195	.85
7474	.35	74196	.79
7475	.49	74197	.75
7476	.35	74198	1.35
7480	.59	74199	1.35
7481	1.10	74221	1.35
7482	.95	74246	1.35
7483	.50	74247	1.25
7484	.50	74248	1.85
7485	.65	74249	1.95
7486	.35	74251	.75
7489	4.95	74259	2.25
7490	.35	74265	1.35
7491	.40	74273	1.95
7492	.50	74276	1.25
7493	.49	74279	.75
7494	.65	74283	2.00
7495	.55	74284	3.75
7496	.70	74285	3.75
7497	2.75	74290	.95
74100	1.00	74293	.75
74107	.30	74298	.85
74109	.45	74351	2.25
74110	.45	74365	.65
74111	.55	74366	.65
74116	1.55	74367	.65
74120	1.20	74368	.65
74121	.29	74376	2.20
74122	.45	74390	1.75
74123	.55	74393	1.35
74125	.45	74425	3.15
74126	.45	74426	.85
		74490	2.55

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1488	.99	UPD765	39.95
1489	.99	8272	39.95
DM8131	2.95	1793	49.95

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74C00	.35	74C373	2.75	4018	.95	4093	.95
74C02	.35	74C374	2.75	4019	.45	4099	1.95
74C04	.35	74C901	.80	4020	.95	14409	8.95
74C08	.35	74C902	.85	4021	.95	14410	8.95
74C10	.35	74C903	.85	4022	1.15	14411	9.95
74C14	1.50	74C905	10.95	4023	.35	14412	12.95
74C20	.35	74C906	.95	4024	.75	14419	2.95
74C30	.35	74C907	1.00	4025	.35	4502	.95
74C32	.50	74C908	2.00	4026	1.65	4503	.65
74C42	1.75	74C909	2.75	4027	.65	4508	1.95
74C48	2.10	74C910	9.95	4028	.80	4510	.95
74C73	.65	74C911	10.00	4029	.95	4511	.95
74C74	.85	74C912	10.00	4030	.45	4512	.95
74C76	.80	74C914	1.95	4034	2.95	4514	1.25
74C83	1.95	74C915	2.00	4035	.85	4515	2.25
74C85	1.95	74C918	2.75	4040	.95	4516	1.55
74C86	.95	74C920	17.95	4041	1.25	4518	1.25
74C89	4.50	74C921	15.95	4042	.75	4519	1.25
74C90	1.75	74C922	5.95	4043	.85	4520	1.25
74C93	1.75	74C923	5.95	4044	.85	4522	1.25
74C95	1.75	74C925	6.75	4046	.95	4526	1.25
74C107	1.00	74C926	7.95	4047	.95	4527	1.95
74C150	5.75	74C927	7.95	4049	.55	4528	1.25
74C151	2.25	74C928	7.95	4050	.55	4531	.95
74C154	3.25	74C929	19.95	4051	.95	4532	1.95
74C157	1.75	74C930	19.95	4053	.95	4538	1.95
74C160	2.00	4000	.35	4060	1.45	4539	1.95
74C161	2.00	4001	.35	4066	.75	4543	2.70
74C162	2.00	4002	.25	4068	.40	4555	.95
74C163	2.00	4006	.95	4069	.35	4556	.95
74C164	2.00	4007	.29	4070	.35	4581	1.95
74C165	2.00	4008	.95	4071	.30	4582	1.95
74C173	2.00	4009	.45	4072	.30	4584	.95
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74C175	2.25	4011	.35	4075	.30	4702	12.95
74C192	2.25	4012	.25	4076	.95	4724	1.50
74C193	2.25	4013	.45	4078	.30	80C07	.95
74C195	2.25	4014	.95	4081	.30	80C95	.85
74C200	5.75	4015	.95	4082	.30	80C96	.95
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T=TO-220 V=8 PIN K=TO-3

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7824T	.99		
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7815K	1.39		
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78L12	.69	79L12	.79
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LM317K	3.95		

T = TO-220 K = TO-3 L = TO-92

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6821	4.95
6828	9.95
6834	16.95
6840	14.95
6843	42.95
6844	44.95
6845	29.95
6847	15.95
6850	4.75
6852	5.75
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6871	25.95
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18 pin ST	.20	.18
20 pin ST	.29	.27
22 pin ST	.30	.27
24 pin ST	.30	.27
28 pin ST	.40	.32
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ST = SOLDERTAIL

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LP = LOW POWER

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74S570	(82S130)	OC	512 × 4	7.80
74S571	(82S131)	TS	512 × 4	7.80

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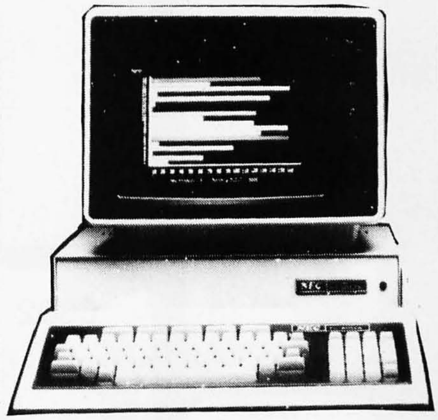

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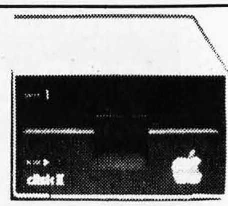

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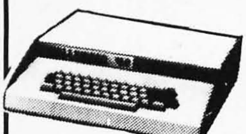

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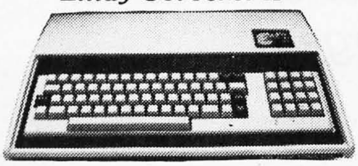

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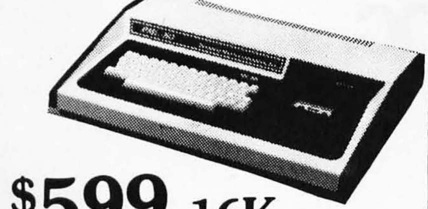

$599 16K

Compatible with TRS-80 Model I hardware and software!

S-100

Quality S-100 cards available now at incredibly low prices.

	Kit	Assm & Tested
CALIFORNIA COMPUTER SYSTEMS		
Z-80 CPU 2810	n/a	229
64K Dynamic Ram board	n/a	499
16K Static Ram 2 MHz	n/a	249
16K Static Ram 4 MHz	n/a	299
Dbl. Density Floppy Disk Controller	n/a	299
12 Slot S-100 Mainframe	n/a	349
SSM		
Z-80 CPU CB-2	219	279
I04 2 par. & 2 ser. I/0 board	189	249
VB-3 80 × 24 Video board	329	379
VB-3 80 × 48 Video board	369	429
VB-2 I/O Mapped video board 64 × 16	159	219
PB1 PROM Prgmmr & EPROM board	139	199
SD SYSTEMS		
EXPANDORAM I (2MHz Uses 4116 dynamic RAM and is expandable to 64K 16K	240	310
32K	255	325
48K	275	345
64K	295	365
EXPANDORAM II (4MHz Uses 4116 or 4164 dynamic RAM, is expandable to 64K or 256K respectively. 16K	250	319
32K	269	339
48K	289	359
64K	305	375
VERSAFLOPPY I Disk controller	250	319
VERSAFLOPPY II Disk controller	299	369
SBC-100 2.5 MHz Z-80 w/I/O	299	369
SBC-200 4 MHz Z-80 w/I/O	299	369
PROM 100 EPROM programmer	210	279

We will beat any currently advertised price on S-100 boards

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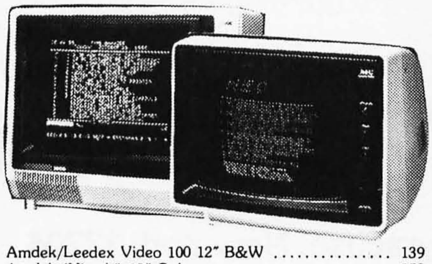
International Telex 695-000 Beta CCMO

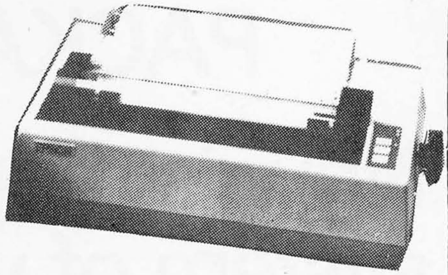
Use your Mastercard, Visa, American Express, Carte Blanche, Diners Club to charge your order phone. Open 7 days.

Video Monitors

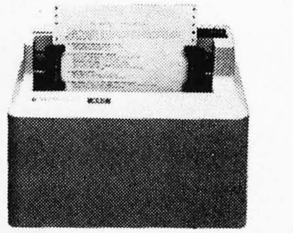


Amdek/Leedex Video 100 12" B&W	139
Amdek (Hitachi) 13" Color	359
NEC 12" Green Phosphor Screen	CALL
NEC 12" RGB Hi-Res Color	CALL
Panasonic 13" Color	449
Sanyo 9" B&W	185
Sanyo 9" Green Phospher Screen	CALL
Sanyo 12" B&W	269
Sanyo 12" Green Phospher Screen	285
Sanyo 13" Color w/excellent resolution	449

PRINTERS



Epson MX-80 **CALL**

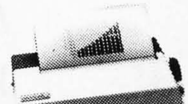


Paper Tiger IDS-460 **$949**

Anadex 9500/9501 w/ 2K Buffer	1299
C. Itoh Starwriter 25 CPS	1499
C. Itoh Starwriter 45 CPS	1899
Espon MX-70	CALL
Epson MX-80 F/T	CALL
Paper Tiger IDS-445	699
Paper Tiger IDS-460	949
Paper Tiger IDS-560	1249
Silentype w/Apple II interface card	349
Qume Sprint 5/45	2495

Silentype w/apple II Interface

$349



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Ordering Information: Phone orders using VISA, MASTERCARD, AMERICAN EXPRESS, DINERS CLUB, CARTE BLANCHE, bank wire transfer, cashiers or certified check, money order, or personal check (allow ten days to clear.) Unless prepaid with cash, please add 5% for shipping, handling and insurance minimum $5.00). California residents add 6% sales tax. We accept COD's. PO's accepted from Educational Institutions. All equipment is subject to price change and availability without notice. All equipment is new and complete with manufacturer's warranty. Showroom prices may differ from mail order advertisement.

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consumer computers

Mail Order

8314 Parkway Drive
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page DIGITAL

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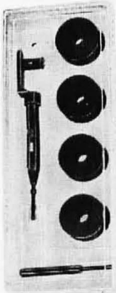
PRODUCTS



JUST WRAP KIT

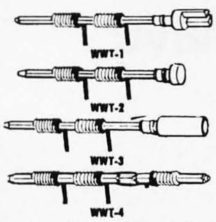
Just Wrap tool for daisy chain wiring. Tool strips as it wraps and cuts. Includes one 50 foot spool of wire.

Part No.	Description	Price
JW-1*	Just Wrap Tool	$14.95
JWK-6	Tool w/4 Spools and JUW1	24.95
R-JW*	50 Ft. Replacement Wire	3.49
JUW-1	Unwrapping Tool	3.49

*Specify Color: Red, Blue, White or Yellow.

HAND WRAP TOOL

Part No.	Description	Price
WSU30	Regular	$6.95
WSU30M	Modified	7.95



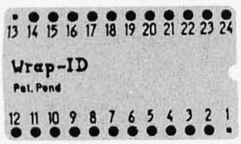
TERMINALS

- .025 (0,63mm) Square Post
- 3 Level Wire-Wrapping
- Gold Plated

25 PER PKG.

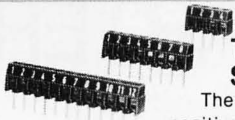
Part No.	Description	Price
WWT-1	Slotted Terminal	$4.98
WWT-2	Single Sided Terminal	2.98
WWT-3	IC Socket Term.	4.98
WWT-4	Double Sided Terminal	1.98
INS 1	Insertion Tool for above	2.49

SOCKET WRAP — ID



Slipped onto socket before wrapping to identify pins.

Part #	Price	Bulk Price	Part #	Price	Bulk Price
14ID	1.49/10	5.50/100	22ID	1.49/5	5.95/50
16ID	1.49/10	5.95/100	24ID	1.49/5	5.95/50
18ID	1.49/10	5.00/50	28ID	1.49/5	6.50/50
20ID	1.49/5	5.00/50	40ID	1.49/5	5.00/25



P.C.B. TERMINAL STRIPS

The TS strips provide positive screw activated clamping action, accommodate wire sizes 14-30 AWG (1,8-0, 25mm). Pins are solder plated copper, .042 inch (1mm) diameter, on .200 inch (5mm) centers.

Part No.	Description	Price
TS- 4	4-Pole	$1.69
TS- 8	8-Pole	2.59
TS-12	12-Pole	3.49
TS6MD	2-Pole Interlocking	3/1.79

DESOLDERING PUMP

Easy one hand operation. Rugged all metal construction. Replaceable TEFLON® Tip. Self cleaning on each stroke. Suction precisely regulated for reliable desoldering without damage to delicate circuitry.

DSPI	Desoldering Pump	$9.95

LOGIC PROBE

Compatible with all logic families using a 4 to 15V power supply. Thresholds automatically programmed. Visual indication of logic levels to show high, low, bad level or open circuit logic pulses.

- 10 N sec. pulse responses
- 120 K input impedence.
- Automatic resetting memory.
- Includes tip with protective cap & coiled cord.

PRB-1 $36.95

LOGIC PULSER

Superimposes a pulse train (20 pps) or a single pulse onto the circuit node under test without un-soldering IC's.

- Automatic polarity sensing
- 2 us pulse width
- Finger tip push button actuated
- Includes tip with protective cap & coiled cord.

PSL-1 $48.95

VACUUM VISE

Unique vacuum-based light duty vise for precision handling of small components and assemblies. Rugged ABS construction. 1½" (32mm) travel for maximum versatility. Also features screw lugs for permanent installation.

VV1	Vacuum Vice	$3.49

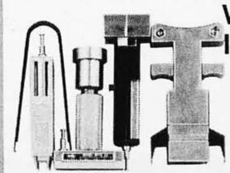
HOBBY-WRAP TOOL BW263

- Auto-Indexing
- Anti-Overwrap
- Modified Wrap

Part No.	Description	Price
BW2630	Tool	$19.85
BT30	#30 Bit (not incl.)	3.95
BT2628	#28 Bit (not incl.)	7.95
BC1	Batteries & Charger	14.95

INSERTION/EXTRACTION TOOLS

Part No.	Description	Price
INS1416	14-16 pin Inserter	$3.49
MOS1416	14-16 pin MOS Safe Inserter	7.95
MOS2428	24-28 pin MOS Safe Inserter	7.95
MOS40	40 pin MOS Safe Inserter	7.95
EX1	14-16 pin IC Extractor	1.49
EX2	24-40 pin IC Extractor	7.95



WK-7 IC INSERTION K

Complete IC Inserter/ Extractor K Individual Components (listed above) $22.95

IC DISPENSER

Allows IC's to be dispensed from their tube 1 at a time and picked up by insertion tools above.

• Dispenses 8-42 pin IC's • Compatable with all IC carrying tubes • Use with WK7 for MOS safe insertion. •

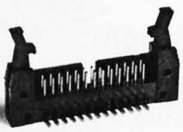
Part No.	Description	Price
MDD1	1 Chan. Dispenser	$21.85
MDD5	5 Chan. Dispenser	83.43
MDD10	10 Chan. Dispenser	160.45

• • *No Discount.

Circle 281 on inquiry card.

LL FREE ORDERING NUMBER 1-(800) 423-7144

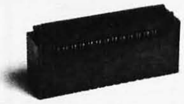
IDC CONNECTORS



RIGHT ANGLE HEADERS

	SOLDER TAIL		WIRE WRAP	
Size	Part No.	Price	Part No.	Price
10	IDH10SRB	$1.20	IDH10WRB	$2.60
20	IDH20SRB	1.90	IDH20WRB	4.15
26	IDH26SRB	2.75	IDH26WRB	5.35
34	IDH34SRB	3.75	IDH34WRB	6.25
40	IDH40SRB	3.75	IDH40WRB	7.35
50	IDH50SRB	4.75	IDH50WRB	9.20

.1" Spacing. Mounts on PC Board & Mates with IDS Socket below. Ejector Bars - 4/1.00.



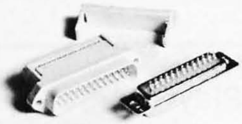
EDGE CARD CONNECTORS

Size	Part No.	Price
10	IDE10B	$3.95
20	IDE20B	4.35
26	IDE26B	5.00
34	IDE34B	6.05
40	IDE40B	6.90
50	IDE50B	7.50

.1" Spacing. Crimps onto cable with ordinary vise & mates with standard .062" Card Edge.

RIBBON CABLE

	Solid Color		Color Coded	
Size	10 ft.	100 ft.	10 ft.	100 ft.
10	2.90	17.00	4.00	30.00
14	3.40	23.80	5.00	42.00
16	3.70	27.20	5.60	48.00
20	4.40	34.00	7.00	60.00
24	5.00	40.80	8.00	72.00
26	5.40	44.20	8.60	78.00
34	6.80	57.80	11.00	102.00
40	7.80	68.00	13.00	120.00
50	9.50	85.00	16.00	150.00



25 PIN "D" CONNECTORS

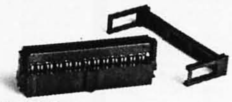
Solder Style	Part No.	Price
Male	DB25P	$2.95
Female	DB25S	3.95
Cover	DB25C	1.50
IDC Style		
Male	IDB25P	6.25
Female	IDB25S	6.60
Cover	IDB25C	1.60

Solder Style solders onto cable, IDC Style crimps onto cable with vise. 9, 15, 37 and 50 pin available also.

CABLE PLUGS

Size	Part No.	Price
14	IDP14B	$1.45
16	IDP16B	1.65
24	IDP24B	2.50
40	IDP40B	4.15

.1" Spacing. Crimps onto cable with ordinary vise & plugs into standard IC Socket.



SOCKETS

Size	Part No.	Price
10	IDS10B	$1.88
20	IDS20B	2.75
26	IDS26B	3.50
34	IDS34B	4.50
40	IDS40B	5.40
50	IDS50B	6.50

.1" Spacing. Crimps onto cable with ordinary vise & mounts to header sold above.

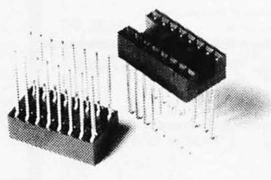
WIRE WRAP SUPPLIES

WIRE WRAP WIRE

#30 Wire Wrap Wire

Length	100/Bag	500/Bag	1K/Bag
2.5"	$1.38	$3.94	$6.81
3.0"	1.43	4.25	7.46
3.5"	1.51	4.57	8.11
4.0"	1.56	4.88	8.73
4.5"	1.63	5.21	9.39
5.0"	1.69	5.54	10.04
5.5"	1.74	5.92	10.69
6.0"	1.82	6.23	11.34
6.5"	2.11	7.08	12.99
7.0"	2.19	7.44	13.68
7.5"	2.29	7.78	14.40
8.0"	2.35	8.12	15.10
8.5"	2.40	8.46	15.80
9.0"	2.46	8.92	16.51
9.5"	2.53	9.15	17.22
10.0"	2.63	9.58	17.91

All lengths are overall, including 1" strip on each end. Choose from colors; Red, Blue, Black, Yellow, White, Green, Orange, and Violet.



Size	Part No.	Each	Tube
08	ICN083WBSG	.44	52x .39 = $20.28
14	ICN143WBSG	.53	30x .46 = $13.80
16	ICN163WBSG	.58	26x .50 = $13.00
18	ICN183WBSG	.78	23x .68 = $15.64
20	ICN203WBSG	1.00	21x .85 = $17.85
22	ICN224WBSG	1.07	19x .92 = $17.48
24	ICN246WBSG	1.09	17x1.09 = $15.98
28	ICN286WBSG	1.43	15x1.23 = $18.45
40	ICN406WBSG	1.85	10x1.60 = $16.00

Selective Plating provides gold in contact where it counts. 3-level wrap. Save by buying sockets by the tube. All gold available at ½¢/pin extra charge.

* * * No Discount

WIRE KITS

Kit No. 1 — $9.95

250	3"	100	4½"
200	3½"	100	5"
100	4"	100	6"

Kit No. 2 — $24.95

250	2½"	250	5"
500	3"	100	5½"
500	3½"	100	6"
500	4"	100	6½"
250	4½"	100	7"

Kit No. 3 — $34.95

250	2½"	500	4½"
500	3"	500	5"
500	3½"	500	5½"
500	4"	500	6"

Kit No. 4 — $59.95

500	2½"	1000	4½"
1000	3"	1000	5"
1000	3½"	1000	5½"
1000	4"	1000	6"

ORDERING INFORMATION

Prepaid orders over $50 shipped prepaid via UPS. All others add $3.00 for handling. VISA, MC, COD's and open account orders will be charged freight. $15 minimum order. $100 minimum open account order.

DISCOUNT SCHEDULE

Order	Amount
$15 - 99	Net
100 - 199	less 10%
200 - 499	less 15%
500 - 999	less 20%
1000 up	less 25%

Discount and the name of this magazine must be mentioned at time of order to get discount. Discount applies on all items except as noted, "No Discount."

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FIRST TO OFFER PRIME PRODUCTS TO THE HOBBYIST AT FAIR PRICES!

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Call For Special School Discounts

SALE 4164 $19.95

V-1000 Vista "V-DRIVE"

Qume DATATRAK 8

THE LAST WORD IN 8" FLOPPY-DISK ENCLOSURES

THE VISTA V-1000 FLOPPY DISK DRIVE SUBSYSTEM ● Deluxe chassis with internal slide easy access for drive positioning and mounting ● Built to mechanically and electrically accomodate single sided drives—including the most popular 8-inch Winchester and Shugart floppy disk drives, and 8-inch streaming tape units ● Storage capacity from 0.5 to 40 megabytes ● Industrial quality cabinet with die cast front bezel ● Meets all UL and OSHA standards ● Additional Savings! Front and rear retma rail mounts provided at no extra charge (no external slides) ● Desk or rack mountable ● Features modular construction with removeable sub-assembly that allows easy cabinet positioning and mounting ● Drives pull out for easy service and maintenance.

DISCOUNT PRICES

CABINET	$ 395
CABINET with (2) single sided drives (Including power supply & cable)	$1495
CABINET with (2) double sided drives (including power supply & cable)	$1995

Vista V-80 5¼" DISK

FOR **TRS 80® MODEL I, PMC 80, ZENITH H89, S-100, etc.**
ONLY 310⁰⁰ ea.
MODEL V-801, 80 TRACKS, SS
ONLY 425⁰⁰ ea.

2 DRIVE CABLE . 29.95 4 DRIVE CABLE . 39.95

MOSTEK MK4015 4K Dynamic RAM

Refresh while supply lasts only **.49¢**
Pin equivalent to MK4027 except has 1 ms.

S-100 WW

$2.99 each

FIRST QUALITY AT SURPLUS PRICE

2708 EPROMS

PRIME-450 Ns.

8 for $29.95

4K STATIC RAM SELL-OFF

Zilog 6104-4

Same as TMS 4044 but designed specifically for Z-80 based systems. This is full-spec 4K × 1 RAM, 450 Ns.

While supply lasts $1.49 each.

SPECIAL PURCHASE

$59.95 Limited Supply $59.95

16K Altair RAM Boards. Fully Populated as is.

FLOPPY DISK DRIVES

QUME® Datatrack 8
- Double Sided
- Double Density

ACP LOW PRICE $569.95

Tandom TM100-1 5¼" Disk Drive	249.95
MPI B51-5¼", 40 tracks	239.95
Shugart SA400-5¼" 35 tracks	295.00
Shugart 800/801R 8"	449.00
Siemens Shugart Compatible Model FDD-120-8D	429.00
PERSCI Model 277 Dual	1195.00
MPI B52 5¼" Dual	348.00
WANGO/SIEMENS 82	290.00
MPI 91 Double Track Density Single Side, 80 Tracks	375.00
MPI 92 Double Track Density Double Side, 160 Track	475.00

6800 MICROMODULE™ PRICE LIST

MODEL NO.	DESCRIPTION	PRICE
9600A	Single Board Microcomputer	$495.00
9609	Advanced Single Bd. Comp. (6809)	595.00
9601	16 Slot Mother Board	175.00
9602	Card Cage	75.00
9603	8 Slot Mother Board	100.00
9604	Power Supply	275.00
9605	DC Input Power Supply	325.00
9610	Utility Proto Board	39.00
9611	Arith. Proc/Memory Module	495.00
9612	Buffered Utility Proto Board	49.00
9616	32K EPROM/RAM Module	250.00
9617	EPROM Programming Head	250.00
9620	16 Channel Parallel I/O Module	295.00
9622	Serial-Parallel I/O Module	325.00
9627	16K Static RAM Module 470ns	395.00
9629	32K Static RAM 450ns	695.00
9629A	32K Static RAM 200ns	895.00
9630	Card Extender	68.00
9640	Multiple Programmable Timer	395.00
9650	8 Channel Duplex Serial I/O Mod.	395.00
9655	Intelligent Tape Controller	550.00
96103	32/32 I/O Module	275.00
96702	Contact Closure Module	350.00

UNPOPULATED BOARDS (Also Available)

$24.95 TRS-80/APPLE $24.95

MEMORY EXPANSION KITS.
4116's, 16K (200/250 ns.)
16K 8 pcs for **$24.95** Specify Computer **RAM**
Call For Volume Pricing

CENTRONICS PRINTER

Model 737
- Centronics complete printer
- The 737 has everything. Check and compare the features.
- New low price **$835.00**

32K STATIC RAM BOARD

2 or 4 MHz Expandable uses 2114L's

S-100

16K 4 MHz Kit	159.95
16K 4 MHz A&T	217.95
32K MHz Kit	289.95
32K 4 MHz A&T	339.00
Bare Board	39.95
Bare Bd. w/all parts less mem	99.95

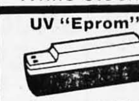
NEW! from Zilog

Z-8 CPU comes with Tiny Basie & debug program on the I.C. **$69.95 w/data**

BIPOLAR CPU SALE

Signetics 8 × 300 8 bit CPU
While stock lasts 14.95 ea.

UV "Eprom" Eraser



Model UVs-11E $69.95
Holds 4 Eprom's at a time
Backed by 45 years experience
Model S-52T... $325.00
Professional Industrial Model

NON-LINEAR SYSTEMS, INC. NLS

TOUCH TEST 20

DIGITAL MULTIMETER **$319⁹⁵**

BECKMAN DIGITAL MULTIMETERS

AS LOW AS 100⁰⁰

TECH 300 Digital Multimeter	$110
TECH 310 Digital Multimeter	$140
TECH 330 Digital Multimeter	$189
VC-201 Vinyl Carrying Case	$10
DC-202 Deluxe Carrying Case	$24
HV-211 High Voltage Probe	$35
RP-221 RP Probe	$35
Ct-231 AC Current Clamp	$42
DL-241 Delxue Test Lead Kit	$10
TL-242 Square Test Leads	$6

INTERSYSTEMS

The Preferred S-100 Box

The new Series II CPU Board features a 4 MHz Z-80A CPU and full-feature front panel. 20-slot actively terminated mother-board, with 25 amp power supply (50/60 Hz operation, incl. 68 cfm fan).

DPS-1, List **$1795**

ACP Price **$1499**

SYSTEM 2A
with Z-80A CPU 4 MHz, 64K RAM, I/O Board, 20 slots, front panel, double density disk controller board. Full 1-year warranty.

List **$3795** ACP Price **$2995**

NEC PC-8000 Series Microcomputer System.

NEW INTRO PRICING $1099.00

- Z-80A CPU 4 MHz
- 5 user programmable function keys
- 82 Keys with numeric keypad
- 160x100 resolution
- 80 character screen

PC-8001A Microcomputer w/32KRAM	$1295.00	1099.00
PC-8012A I/O Unit w/32K RAM, Expansion slots	795.00	699.00
PC-8031A Dual Mini-Disk Drive Unit	1295.00	1099.00
PC-8032A Add-On Dual Mini-Disk Drive Unit	1095.00	949.00
PC-8023A Impact Matrix Printer, Tractor/Friction Feed	860.00	769.00
PC-8094A Cable for PC-8023A Printer	49.95	44.95
JB-1201M(A) High Resolution Green Monitor	265.00	239.00
JC-1202DH(A) High Resolution Color Monitor w/RGB Input	1195.00	1049.00
PC-8091A RGB Cable for JC-1202DH(A) Color Monitor	19.95	17.95
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2114L-250ns. (4045)	6.50	5.95	5.50
2114L-450ns. (4045)	4.75	4.25	3.95
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16	.20	.38	.62
18	.24	.59	.84
20	.29	.69	.99
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FND508	500	Red	Comm. Anode (+1)	.99
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FND550	500	Orange	Comm. Cathode	1.49
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FND807 (810)	800	Red	Comm. Anode	1.75
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HP5082-7731	300	Red	Comm. Anode	.75
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LM339	.79	74157	.49
LM710CN	.29	74161	.49
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IQ135	$899
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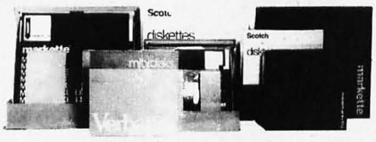

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Double side/double D.	743-0	65.	59.		na.		3115	49.	45.

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$3495

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Discus 2+2 2 drives	2237	"New" Multiboard	275
		M-10 Ten Megabyte hard	2550

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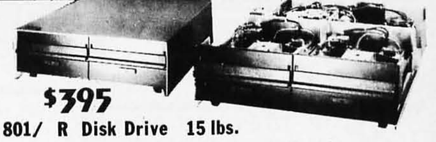
These diskettes are "UNBRANDED" but are guaranteed first quality Memorex Brand. (#3060 single den.)

Like all diskettes sold by California Digital, a library case is supplied free with the purchase of every box.

This offer is subject to remaining inventory on hand.

Shugart Associates



$395

801/ R Disk Drive 15 lbs.

Shugart 801/R with CP 206 power supply, muffin exhaust fan, complete in dual enclosure with all the necessary harnessing cables. Documentation included. 36 pounds. MSD-1801 **$795**

Same as above but with two Shugart 801R disk drives. 50 pounds. MSD-2801 **$1195**

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16k memory (8) 4116's

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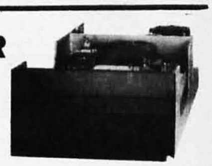
Ultrasonic Controller	19.95	NEW full control wall switch	14.50



SHUGART 801R $395

Qume Double Sided 8 Disk Drive $575

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4116 150ns	3.75	3.50	3.25	3.00
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2114L4 450ns	3.95	2.95	2.75	2.50
2114L3 300ns	4.25	3.75	3.00	2.75
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4044-2 250ns	5.50	4.95	4.50	4.35
5257-3 300ns	4.47	4.25	4.05	3.75

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2716 tri-volt	9.95	9.00	8.25	7.50
2732 Intel	19.00	17.50	16.00	
2532 TI	21.50	19.00		
2764	*			

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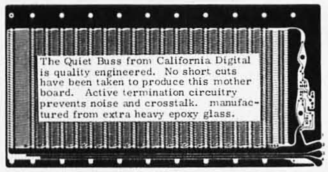
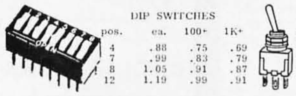
Quiet Buss 8803-18 18 slot IMSAI



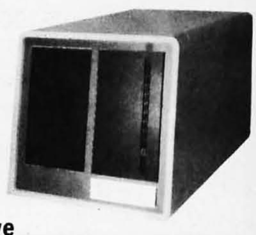
The Quiet Buss from California Digital is quality engineered. No short cuts have been taken to produce this mother board. Active termination circuitry prevents noise and crosstalk. manufactured from extra heavy epoxy glass.

SWITCHES



DIP SWITCHES pos.	ea.	100+	1K+
4	.88	.75	.69
7	.99	.83	.79
8	1.05	.91	.87
12	1.19	.99	.91

TOGGLE	ea.	100+
7101 on/on	1.19	.98
7103 on/off/on	1.39	1.19
7107 mnt. on	1.39	1.19
7108 mnt. on	1.39	1.19
7205 dpdt mnt	1.85	1.65



NEW from Shugart Technology 5 Megabyte Hard Disk Drive

Packaged in the same physical size as the industry standard 5 1/4" minifloppy disk drive. The micro-Winchester stores thirty times as much data (6.38 megabytes unformatted), accesses data twice as fast (170 milliseconds) and transfers data twenty times faster (5.0 megabits per second.)

The ST506 is factory sealed to protect the media from environmental contaminates. Requires only DC voltage.

Dual California Digital 5 1/4" enclosure, ST506 drive and power supply. **$1500**

Shugart Associates SA400 removable media disk drive for above package. add: **$300**

S-100 & Apple controller scheduled for spring release.

CONNECTORS

GOLD EDGE CONNECTORS	each	10+
S-100 .125" centers		
Imsai solder .250" row	$2.95	$2.50
Imsai wire wrap (TI)	3.95	3.50
Sullins Hi-Rel. .250"	4.50	4.00
Sullins Hi-Rel. W/W	5.35	4.90
Sullins /Altair .140"	4.95	4.50
.156" Centers (standard)		
22/44 Kim Eyelet	2.50	2.15
36/72 Digital Group S/T	5.95	5.50
36/72 Digital Group W/W	6.60	6.15
43/86 Motorola 6800 S/T	6.60	6.15
43/86 Moto. 6800 W/W	7.00	6.85

INTEGRATED CIRCUIT SOCKETS

	Low Profile each	100+	Wire Wrap each	100+
8 pin	$.10	$.09	$.46	$.41
14 pin	.10	.09	.45	.41
16 pin	.12	.11	.50	.45
18 pin	.15	.13	.68	.61
24 pin	.26	.24	.94	.87
40 pin	.42	.40	1.60	1.47

"D" Type	each	10-24	25+
DE9P male	$1.60	$1.40	$1.30
DE9S female	2.25	2.00	1.90
DE hood	1.50	1.35	1.20
DA15P male	2.35	2.15	2.00
DA15S female	3.25	3.10	2.90
DA hood 2/P	1.60	1.35	1.30
DB25P male	2.50	2.35	2.25
DB25S female	3.35	3.15	3.05
DB hood 2/P	1.35	1.15	1.05
DC37P male	4.20	4.00	3.70
DC37S female	6.00	5.75	5.50
DC hood 2/P	2.25	2.00	1.75
DD50P male	5.50	5.10	4.75
DD50S female	9.40	8.60	8.00
DD50 hood 2/P	2.60	2.40	2.10
CENTRONICS			
57-30360	7.95	6.75	5.75
RIBBON CABLE CONNECTORS			
17/34 5" disk	4.85	4.15	3.95
20/40 TRS-80	5.65	5.05	4.70
25/50 8" disk	5.90	5.15	4.90

DATA INPUT TERMINAL

This Keystation terminal was recently acquired from the CMC division of the Pertec Corporation. The unit was originally designed for inputing data directly onto magnetic tape.

The system is comprised of a premium cast aluminium and fiberglass enclosure, along with a Honeywell / Microswitch hall effect keyboard. Thirty display lamps advise the operator of the systems status. Four inch loud speaker acknowledges acceptance of data and alerts the operator of pending problems.

But most of all this "USED" terminal, with a little imagination, can be engineered to make the perfect home for an S-100 computer and video display; or with slight modification will accept the Rockwell AIM-65 micro/computer.

Five volt regulated power supply is available for an additional $20. All units are in excellent condition. Original acquisition over $700. 22 lbs.

direct connect MODEM — Your Choice $169

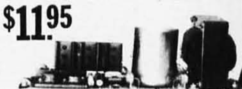
Direct connect modems eliminate loss of information due to the carbon compression associated with acoustic modems. Choose either of these two great units.

The Universal Data Systems 103LP is switch selectable between answer and originate modes. Fully Bell 103 compatable. Directly connects to the new modular telephone jack. 100% powered from the telephone line. No need to locate modem in proximity to A.C. power recepticle. MOD-103LP 2 pounds.

Novation "D" Cat connects to most of the new "Bell" modular handsets. Ideal for multiple line office telephones. Requires external A.C. power. MOD-DCAT 2 Lb.

UDS 103J/LP AUTO ANSWER $219

Regulated Power Supply 5 VOLT 5 AMP $11.95



This USED surplus power supply was removed from working equipment. Pass transistor regulation outputs five volts at a conservative five amps Suitable for TTL hobby applications. SPC-PS1 8 pounds.

VISA — master charge

All merchandise sold by California Digital is premium grade. Shipping: First five pounds $2.00; each additional add $.40 Foreign orders 10% shipping. Excess will be refunded. California residents add 6% sales tax. COD's discouraged. Open accounts extended to state supported educational institutions and companies with a "Strong Dun & Bradstreet." Warehouse: 15608 Inglewood Blvd. Visitors by appointment.

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TECHNICAL & CALIFORNIA (213) 679-9001

TWX 910 325-6212

Circle 51 on inquiry card.

California Digital

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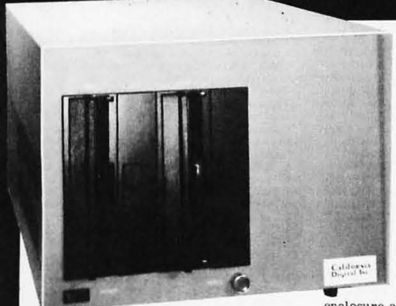


Enclosure for Two 8" Disk Drives and 12 Slot Motherboard

$375

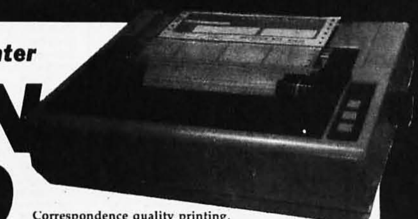
Modular in concept... designed for cost effective system integration. Buy as much as you require. The basic enclosure is engineered from welded structural steel. RF line filter insures that the enclosure conforms to the Federal Communication Commission RFI requirements. Two exhaust fans provide maximun airflow across printed circuit cards. The enclosure has mounting provisions for two 8" Qume for Shugart disk drives and a 10 megabyte Winchester drive. The basic package is supplied with two AC accessory receptacles and all AC and DC power cables. Rear panel has been machined to accept nine assorted computer connectors. Shipping weight 30 lbs. ENM-2D $375.00

POWER SUPPLY mounts into basic enclosure, supports two 8" disk drives and 12 slot motherboard. Shipping weight 15 lbs. PSS-2D $99.00

MOTHERBOARD with noise canceling basket-weave ground plane. Complete with twelve gold S-100 edge connectors and card cage. Shipping weight 3 lbs. BDB-MTH12C $99.00

World's Best Selling Printer

EPSON MX80



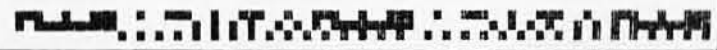
Immediate Delivery

Only $475

Correspondence quality printing.
A lot of printers costing a lot more can't touch the MX-80's performance. It gives you a choice of 40, 80, 66 or 132 columns of printing in as many as four distinct printing density modes, a total of twelve different combinations which can accommodate nearly any printing requirement.

Bidirectional printing. Logical seeking of shortest lines. 80 CPS. 64 graphics characters. Forms handling. The list of standard features goes on and on. The fact is that there are few printers that can compete with the MX-80 at ANY price. And none—ZERO—in its extraordinarily affordable price range.

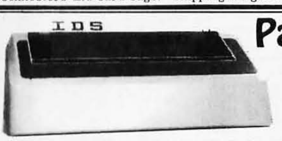
ABCDEFGHIJKLMNOPQRSTUVWXYZABCDEFGHIJ



Paper Tiger 560G

IDS

$1350



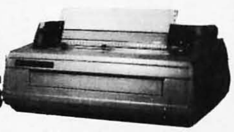
IBM 3101 Display Terminal

IBM Direct Price $1295

California Digital discount price **$1195**

NEC Spinwriter 5510P/S $2795

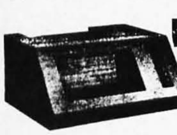
The word processing quality Spinwriter prints at speeds upto 55 characters per second. The Model 5510 P/S is supplied with both parallel and RS-232 serial interfacing. Also included is the tractor feed mechanism, along with print thimble and ribbon. PRN-5510PS 70 lbs. Keyboard (KSR) Model 5520 P/S available $2995. PRN-5520PS 75 lbs.



AMPEX DIALOGUE 80 CRT TERMINAL

$995

New from the Ampex Corporation. The Dialogue 80 features removable keyboard, displayable two pages (four optional) dual program keys, half intensity protected fields and status line. Transmits data either block, line or character mode. Excellent value. VDT-D80 shipping 47 lbs.

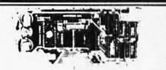


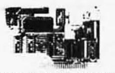
PRINTRONIX

P-300 $4500

P-600 $6150

ACCESSORIES FOR THE APPLE COMPUTER





CALIFORNIA COMPUTER SYSTEMS	
Arithmetic Processor 7811 B/C	$319
Asynchronous serial interface 7710	129
Centronics Interface card 7728	95
12K PROM Module 7114	69
Calender/Clock, Bat. back-up 7424	99
Parallel Interface 7720A	99
Programable Timer 7740A	99
Analog/Digital converter 7470A	99
MICROSOFT PRODUCTS	
Apple to Z-80 CPU card	379
D. C. HAYES PRODUCTS	
Micromodem for Apple	319
COMPUTER STOP PRODUCTS	
Double Vision / 80 Column Video	250
INTERACTIVE STRUCTURES	
16 Channel A/D card AIO/2	275
MOUNTAIN COMPUTER PRODUCTS	
Intro X-10 system for BSR	$239
Intro X-10 card only	165
16 channel AD/DA 8 bit	319
Apple Clock battery back-up	225
Supertalker SD200	245
ROM Plus with filter	165
ROM Writer/Programmer	149
APPLE BRAND PRODUCTS	
Apple Language card	450
Floppy disk with controller	560
Floppy disk without controller	495
Apple parallel interface	175
SSM MICROCOMPUTER	
Dual serial parallel interface AIO	
SORRENTO VALLEY ASSOCIATES	
8" floppy controller (Pascal)	360

PRINTERS

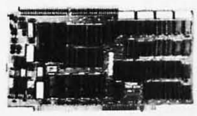
Epson MX80	PREMX80	$475
Epson MX80FT	PREMX80F	595
Epson MX100	PREMX100	825
Anadex 9500	PRA9500	1295
Anadex 9501	PRA9501	1295
Anacom 150	PRA150	1075
IDS Paper Tgr.	PRG460G	1095
IDS Tiger 560	PRG560G	1350
Diablo 630	PRD630	2150
Diablo 1650	PRD1650	2850
Diablo 1640	PRD1640	2496
Datasouth 180	PRD180	1350
Printronix 300	PRP300	4500
Printronix 600	PRP600	6150
NEC/Sellum 1	PRN5510ps	2695
NEC/Sm 16K	PRN5516ps	2795
TEC/Starwrit.	PRV300	1395
Okidata 80	PRO80	419
Okidata 82	PRO82	619
Okidata 83	PRO83	895
Teletype 43K	PTT4320K	1095
Texas Ins. 810	PRT810B	1450
Tex. Ins 810C	PRT810C	1795
Centronics 730	PRC730P	529
Centronics 737	PRC737P	695
Centronics 739	PRC739P	795
Centrnx 704-9	PRC704-9	1495
Centrnx.704-11	PRC704-11	1569

VIDEO TERMINALS

ADDS Regent 25 numeric cluster	VDT-R25	$850
ADDS Regent 30 25th status line	VDT-R30	950
ADDS Regent 40 limited graphics	VDT-R40	1195
ADDS Regent 60 Block mode	VDT-R60	1495
Ampex Dialouge 80 two page, detatch	VDT-D80	995
Digital Equipment VT-100	VDT-V100	1595
Digital Equipment VT-132	VDT-V132	1895
Direct VP-800A emulator	VDT-P800	call
Hazeltine 1410	VDT-H1410	750
Hazeltine 1420	VDT-H1420	795
Hazeltine 1500	VDT-H1500	850
Hazeltine 1510	VDT-H1510	1025
Hazeltine 1520	VDT-H1520	1225
Hewlett Packard 2621A	VDT-HP21A	
Hewlett Packard 2621P	VDT-HP21P	
IBM 3101-10 character mode green	VDT-3101	1195
IBM 3101-20 block mode	VDT-31012	1395
Lear Seigler 3A upper case only	VDT-L3A	850
Lear Seigler ADM5	VDT-L5	945
Lear Seigler ADM31	VDT-L31	1385
Lear Seigler ADM42	VDT-L42	1995
Soroc IQ 120	VDT-Q120	675
Soroc IQ 135 NEW	VDT-Q135	850
Soroc IQ 140 detatchable keyboard	VDT-Q140	1150
Televideo 912C	VDT-T912	665
Televideo 920C	VDT-T920	745
Televideo 950C detatchable keybd.	VDT-T950	985
Zenith Z-19	VDT-Z-19	735

S-100 BOARDS

Assembled • Tested • Burned-in



CPU BOARDS		
Calif. Computer 2810A Z-80 DMA, 4MHz	BDC-C2810	$250
Godbout Z-80 24 bit, 4MHz	BDC-GZ80	239
Godbout 8085/8088 dual 16 bit processor	BDC-G88	375
Measurement Systems Z-80 4 serial 2 parallel real time clock, 8 vector	BDC-MZ80	395
SD Systems SBC-200 Z-80 with serial & parallel I/O ports	BDC-SBC2	385
Teletek FDC-1 single board CPU & floppy disk controller plus I/O	BDC-FDC1	695
MAINFRAMES		
Calif. Computer 2200A 12 slot & power supply	ENM-C2200	349
TEI 12 slot table	ENM-T12	495
TEI 22 slot table	ENM-T22	650
Godbout mainfrm.	ENM-GMF	
MEMORY BOARDS		
Calif. Computer 2065A 64K dyamic memory	BDM-C2065	$429
Calif. Computer 2016 16K static memory	BDM-C2016	259
Calif. Computer 2032 32K static memory	BDM-C2032	585
Godbout Ram 17 64K static memory 16 bit	BDM-G17	1025
SD Systems Expandoram II 16K dynamic	BDM-EX16	295
64K dynamic	BDM-EX64	375
Measurement Systems DMB6400 for Alpha Micro	BDM-M6400	685
EPROM BOARDS		
Digital Research 32K, 2716 proms extra	BDM-DP32	99
SD Systems Prom-100 programmer	BDM-P100	250
FLOPPY DISK CONTROLLER		
Calif. Computer 2422A with 2.2 CPM	BDF-C2422	329
Godbout "Disk One" features the NEC 765 controller. DMA arbitration	BDF-GD1	395
Measurement Systems 765 chip. single & double density. Error recovery	BDF-MF	419
SD Systems Versafloppy II double density	BDF-VF2	419
Tarbell D/D	BDF-TF2	419
Morrow Design Disk Jockey I single density	BDF-DJ1	195
Morrow Design Disk Jockey II double density	BDF-DJ2	345
INTERFACE BOARDS		
Calif. Computer 2718 I/O 2 serial/2 par'l	BDT-C2718	
Morrow Designs Switchboard 2 serial/4 parl	BDT-MSB	219
Morrow Designs Multiboard 3 serial/3P. +++	BDT-MMB	275
Godbout Interfacer One 2 serial/2 par'l	BDS-GE1	199
Godbout Interfacer Two 1 serial/3 par'l	BDS-GB2	199
SPECIALITY BOARDS		
QT Computer real time clock/calendar	BDS-QCK	135
Artec Elec. Wire wrap prototype board	BDS-AWW	25
Artec Elec. General Purpose proto board	BDS-AGP	25
Godbout Spectrum color board	BDS-GSC	295
D. C. Hayes S-100 Micromodem	BDS-HM1	350
Mullen Products extender board & logic probe kt	BDS-MTB1	49
Mullen Products Opto-contro board kit	BDS-MOC	139

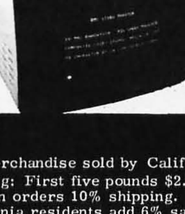
SYSTEMS

APPLE II 48K MEMORY **$1170**

$2650 HEWLETT PACKARD **HP85**

Hew/Pack 85	SYSHP85	2650
Hew/Pack 83	SYSHP83	1895
Altos ACS8000	SYSACS8000	4795
Osborne 1	SYSOB1	1795
Commodore	SYSC8032	1495
Commodore	SYSC8096	1795
Superbrain64Q	SYSSB64Q	$3350
Superbrain64D	SYSSB64D	2850
Northstar 64Q	SYSN64Q	3295
Northstar 64D	SYSN64D	2895
NEC/PC8000	SYSPC8000	call
Apple II Plus	SYSAP	1170

VIDEO MONITORS



BMC KG12C 18MHz P-31 grn phosphor	$259
Leedex/Amdek 12"100	129
Leedex 100 green	169
Leedex 100-80	197
Hitachi color 13"	389
Zenith color 13"	379
NEC green phosphor	219
Panasonic color 10"	
Sanyo 9" BW	149
Sanyo 12" green phos.	235
Sanyo 15" BW	259
Sanyo 13" color	419

Rotron Muffin Fan

$14.77 $12.00 @ 100, 10.50 @ 1000

115 VAC. 7 Watts WR2A1
Factory fresh Muffin fans
NOT pull-outs. EMF-4M

VISA

master charge

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Circle 51 on inquiry card.

7400

Part	Price	Part	Price	Part	Price
SN7400N	.25	SN7472N	.29	SN74156N	.79
SN7401N	.20	SN7473N	.35	SN74157N	.69
SN7402N	.25	SN7474N	.35	SN74160N	.89
SN7403N	.25	SN7475N	.49	SN74161N	.89
SN7404N	.25	SN7476N	.35	SN74162N	.89
SN7405N	.29	SN7479N	5.00	SN74163N	.89
SN7406N	.35	SN7480N	.50	SN74164N	.89
SN7407N	.35	SN7482N	.99	SN74165N	.89
SN7408N	.29	SN7483N	.69	SN74166N	1.25
SN7409N	.29	SN7485N	.89	SN74167N	2.79
SN7410N	.25	SN7486N	.35	SN74170N	1.95
SN7411N	.29	SN7489N	1.75	SN74172N	4.95
SN7412N	.35	SN7490N	.49	SN74173N	1.39
SN7413N	.40	SN7491N	.59	SN74174N	.99
SN7414N	.69	SN7492N	.45	SN74175N	.89
SN7416N	.29	SN7493N	.45	SN74176N	.79
SN7417N	.29	SN7494N	.69	SN74177N	.79
SN7420N	.25	SN7495N	.69	SN74179N	1.49
SN7421N	.29	SN7496N	.69	SN74180N	.79
SN7422N	.45	SN7497N	3.00	SN74181N	2.25
SN7423N	.29	SN74100N	1.49	SN74182N	.79
SN7425N	.29	SN74104N	.89	SN74184N	2.49
SN7426N	.29	SN74105N	.89	SN74185N	2.49
SN7427N	.25	SN74107N	.35	SN74190N	1.25
SN7428N	.49	SN74109N	.39	SN74191N	1.25
SN7430N	.25	SN74116N	1.95	SN74192N	.89
SN7432N	.29	SN74121N	.39	SN74193N	.89
SN7437N	.25	SN74122N	.55	SN74194N	.89
SN7438N	.40	SN74123N	.59	SN74195N	.69
SN7439N	.25	SN74125N	.49	SN74196N	.89
SN7440N	.20	SN74126N	.49	SN74197N	.89
SN7441N	.89	SN74132N	.75	SN74198N	1.49
SN7442N	.59	SN74136N	.75	SN74199N	1.49
SN7443N	1.10	SN74141N	.99	SN74221N	1.25
SN7444N	1.10	SN74142N	3.25	SN74251N	.99
SN7445N	.89	SN74143N	3.49	SN74276N	1.95
SN7446N	.79	SN74144N	3.49	SN74279N	.79
SN7447N	.69	SN74145N	.79	SN74283N	1.49
SN7448N	.79	SN74147N	1.95	SN74284N	3.95
SN7450N	.20	SN74148N	1.29	SN74285N	3.95
SN7451N	.20	SN74150N	1.25	SN74365N	.69
SN7453N	.20	SN74151N	.69	SN74366N	.69
SN7454N	.20	SN74152N	.69	SN74367N	.69
SN7459A	.25	SN74153N	.79	SN74368N	.69
SN7460N	.20	SN74154N	1.25	SN74390N	1.49
SN7470N	.29	SN74155N	.79	SN74393N	1.49

74LS

Part	Price	Part	Price	Part	Price
74LS00	.29	74LS92	.75	74LS192	1.15
74LS01	.29	74LS93	.75	74LS193	1.15
74LS02	.29	74LS95	.99	74LS194	1.15
74LS03	.29	74LS96	1.15	74LS195	1.15
74LS04	.35	74LS107	.45	74LS197	1.19
74LS05	.35	74LS109	.45	74LS221	1.19
74LS08	.35	74LS112	.45	74LS240	1.49
74LS09	.35	74LS113	.49	74LS241	1.49
74LS10	.35	74LS114	.49	74LS242	1.49
74LS11	.39	74LS122	.89	74LS243	1.49
74LS12	.35	74LS123	1.25	74LS244	1.49
74LS13	.59	74LS125	.59	74LS245	2.95
74LS14	.99	74LS126	.59	74LS247	1.19
74LS15	.35	74LS132	.99	74LS248	1.19
74LS20	.35	74LS133	.49	74LS249	1.19
74LS21	.35	74LS136	.49	74LS251	.99
74LS22	.35	74LS138	.89	74LS253	.99
74LS26	.35	74LS139	.89	74LS257	.89
74LS27	.35	74LS151	.89	74LS258	.89
74LS28	.35	74LS153	.89	74LS260	.69
74LS30	.35	74LS154	1.75	74LS266	.69
74LS32	.35	74LS155	.89	74LS273	1.95
74LS33	.59	74LS156	.89	74LS279	.89
74LS37	.45	74LS157	.89	74LS283	.89
74LS38	.39	74LS158	.89	74LS290	.99
74LS40	.35	74LS160	1.15	74LS293	.99
74LS42	.89	74LS161	1.15	74LS298	1.25
74LS47	.89	74LS162	1.15	74LS352	1.29
74LS48	1.15	74LS163	1.15	74LS353	1.29
74LS49	1.15	74LS164	1.15	74LS365	.69
74LS51	.35	74LS165	1.15	74LS366	.69
74LS54	.35	74LS168	1.19	74LS367	.69
74LS55	.35	74LS169	1.19	74LS368	.69
74LS73	.45	74LS170	1.95	74LS373	1.95
74LS74	.45	74LS173	.99	74LS374	1.95
74LS75	.59	74LS174	.99	74LS375	.89
74LS76	.45	74LS175	.99	74LS386	.69
74LS78	.49	74LS181	2.95	74LS393	2.49
74LS83	.89	74LS190	1.25	74LS399	2.49
74LS85	1.25	74LS191	1.25	74LS670	2.49
74LS86	.49			81LS95	1.95
74LS90	.69			81LS97	1.95

74S

Part	Price	Part	Price	Part	Price
74S00	.45	74S124	3.95	74S243	3.25
74S02	.45	74S133	.55	74S244	3.25
74S03	.45	74S134	.69	74S251	1.45
74S04	.55	74S135	1.19	74S253	1.45
74S05	.55	74S136	1.75	74S257	1.35
74S08	.50	74S138	1.35	74S258	1.35
74S09	.50	74S139	1.35	74S260	.79
74S10	.45	74S140	.79	74S280	2.95
74S11	.45	74S151	1.35	74S287	3.25
74S15	.45	74S153	1.35	74S288	2.75
74S20	.45	74S157	1.35	74S373	3.49
74S22	.45	74S158	1.35	74S374	3.49
74S30	.45	74S160	2.95	74S387	2.95
74S32	.55	74S174	1.59	74S471	19.95
74S38	1.25	74S175	1.59	74S472	10.95
74S40	.50	74S188	2.95	74S473	10.95
74S51	.45	74S194	1.95	74S474	12.95
74S64	.50	74S195	1.95	74S475	12.95
74S65	.50	74S196	1.95	74S570	5.95
74S74	.75	74S240	2.95	74S571	5.95
74S86	.79	74S241	2.95	74S572	9.95
74S112	.79	74S242	3.25	74S573	9.95
74S113	.79			74S940	3.15
74S114	.79			74S941	3.15

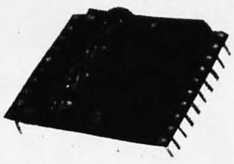
CA—LINEAR

Part	Price	Part	Price	Part	Price
CA3010H	.99	CA3060N	3.25	CA3089N	3.75
CA3013H	2.15	CA3080H	1.25	CA3096N	3.95
CA3023H	3.25	CA3081N	2.00	CA3130H	1.39
CA3035H	2.49	CA3082N	2.00	CA3140H	1.25
CA3039H	1.35	CA3083N	1.60	CA3160H	1.25
CA3046N	1.30	CA3086N	.85	CA3401N	.59
CA3059N	3.25			CA3600N	3.50

CD—CMOS

Part	Price	Part	Price	Part	Price
CD4000	.39	CD4041	1.49	CD 4098	2.49
CD4001	.39	CD4042	.99	CD4506	.75
CD4002	.39	CD4043	.89	CD4507	.99
CD4006	1.19	CD4044	.89	CD4508	3.95
CD4007	.25	CD4046	1.79	CD4510	1.39
CD4009	.49	CD4047	2.50	CD4511	1.29
CD4010	.49	CD4048	1.35	CD4512	1.49
CD4011	.39	CD4049	.49	CD4514	3.95
CD4012	.25	CD4050	.69	CD4515	2.95
CD4013	.49	CD4051	1.19	CD4516	1.49
CD4014	1.39	CD4052	1.19	CD4518	1.79
CD4015	1.19	CD4053	1.19	CD4519	.89
CD4016	.59	CD4056	2.95	CD4520	1.29
CD4017	1.19	CD4059	9.95	CD4526	1.79
CD4018	.99	CD4060	1.49	CD4528	1.79
CD4019	.49	CD4066	.79	CD4529	1.95
CD4020	1.19	CD4068	.39	CD4543	2.79
CD4021	1.39	CD4069	.45	CD4562	11.95
CD4022	1.19	CD4070	.55	CD4566	2.79
CD4023	.29	CD4071	.49	CD4583	2.49
CD4024	.79	CD4072	.49	CD4584	.75
CD4025	.23	CD4073	.49	CD4723	1.95
CD4026	2.95	CD4075	.39	CD4724	1.95
CD4027	.69	CD4076	1.39	MC14409	14.95
CD4028	.89	CD4078	.55	MC14410	14.95
CD4029	1.49	CD4081	.39	MC14411	14.95
CD4030	.49	CD4082	.39	MC14412	11.95
CD4034	3.49	CD4093	.99	MC14419	4.95
CD4035	.99			MC14433	13.95
CD4040	1.49			MC14538	2.49
				MC14541	1.95

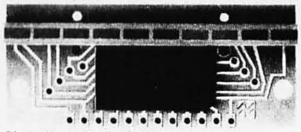
4-Digit 16 Segment Alphanumeric Intelligent Display with Memory, Recorder, Driver



End-stackable, 4-character package. High contrast, 160mil high, magnified monolithic characters. 64-Character ASCII format. Built-in memory, decoder, multiplexer and drivers. Direct access to each digit independently and asynchronously. Five volt logic, TTL compatible. Five volt power supply only. Independent cursor function. Size: 1"L x 1-3/16"H x .225"D.

DL-1416 Alphanumeric Display $19.95 ea.

10-Segment Bargraph Displays
(with On-Board Driver IC-Chip)



Size: 2"L x 7/8"H x 3/16"D

bar or dot display mode externally selectable by user. Packages are end-stackable for expanded displays. Can be cascaded to 10 arrays (100 bargraph elements). LED current programmable from 2mA to 30mA. Stable internal voltage reference for full scale analog inputs from 1.2 to 12V. Each LED output of driver IC with external access. Size: 2"x7/8"x3/16".

NSM3914	Linear Function (10 bars red)	$6.95
NSM39146	Linear Function (6 bars green/4 red)	6.95
NSM3915	Logarithmic Function (10 bars red)	5.95
NSM39158	Logarithmic Func. (6 grn./2 yell./2 rd.)	6.95
NSM3916	VU-Meter Function (10 bars red)	5.95
NSM39168	VU-Meter Func. (6 grn./2 yell./2 rd.)	6.95

DISCRETE LEDS

XC556R	.200"	red	5/$1	MV50	.085"	red	6/$1
XC556G	.200"	green	4/$1	XC209R	.125"	red	5/$1
XC556Y	.200"	yellow	4/$1	XC209G	.125"	green	4/$1
XC556C	.200"	clear	4/$1	XC209Y	.125"	yellow	4/$1
XC22R	.200"	red	5/$1	XC526R	.185"	red	5/$1
XC22G	.200"	green	4/$1	XC526G	.185"	green	4/$1
XC22Y	.200"	yellow	4/$1	XC526Y	.185"	yellow	4/$1
MV10B	.170"	red	4/$1	XC526C	.185"	clear	4/$1

.200(T1¾) Red/Green

Diffused Bi-Color LED

Part No.	1-99	100+
XC5491	.79	.69

XC556 RED LED, METAL MTG. HDW. 2-6" LEADS.

RL-2 . . $.39 ea. or 3/$1.00

DISPLAY LEDS

C.A. — Common Anode
D.D. — Double Digit
C.C. — Common Cathode
RHD — Right Hand Decimal

Type	Polarity	Ht	Price	Type	Polarity	Ht	Price
MAN 1	C.A.—red	.270	2.95	DLG507	C.A.—green	.500	1.25
MAN 2	5x7 D.M.—red	.300	4.95	DL704	C.C.—red	.300	1.25
MAN 3	C.C.—red	.125	.25	DL707	C.A.—red	.300	1.25
MAN 52	C.A.—green	.300	.99	DL728	C.C.—red	.500	1.49
MAN 54	C.C.—green	.300	.99	DL741	C.A.—red	.600	1.25
MAN 71	C.A.—red	.300	.75	DL747	C.A.—red	.600	1.49
MAN 72	C.A.—red	.300	.75	DL750	C.C.—red	.600	1.49
MAN 74	C.C.—red	.300	1.25	DLO847	C.A.—orange	.800	1.49
MAN 82	C.A.—yellow	.300	.49	DLO850	C.C.—orange	.800	1.49
MAN 84	C.C.—yellow	.300	.99	DL338	C.C.—red	.110	.35
MAN 3620	C.A.—orange	.300	.49	FND358	C.C. ± 1	.357	.99
MAN 3630	C.A.—orange ± 1	.300	.99	FND357	C.C.	.357	.75
MAN 3640	C.C.—orange	.300	.99	FND500	C.C. (FND503)	.500	.99
MAN 4610	C.A.—orange	.400	.99	FND507	C.A. (FND510)	.500	.99
MAN 6610	C.C.—orange—DD	.560	.99	HDSP-3401	C.A.—red	.800	1.50
MAN 6630	C.A.—orange ± 1	.560	.99	HDSP-3403	C.C.—red	.800	1.50
MAN 6640	C.C.—orange—DD	.560	.99	HDSP-3406	C.C. red ±1	.800	1.50
MAN 6650	C.C.—orange ± 1	.560	.99	5082-7751	C.A., R.H.D.—red	.430	1.25
MAN 6660	C.A.—orange	.560	.99	5082-7760	C.C., R.H.D.—red	.430	1.25
MAN 6710	C.A.—red—DD	.560	.99	5082-7300	4x7 Numeric (RHD)	.600	22.00
MAN 6740	C.C.—red—DD	.560	.99	5082-7302	4x7 Numeric (LHD)	.600	22.00
MAN 6750	C.C.—red ± 1	.560	.99	5082-7340	4x7 Hxdcl. (0-9/A-F)	.600	22.50
DLO304	C.C.—orange	.300	1.25	4N28	Photo Xsistor Opto-Isol.		.69
DLO307	C.A.—orange	.300	1.25	LIT-1	Photo Xsistor Opto-Isol.		.69
DLG500	C.C.—green	.500	1.25	MOC3010	Optically Isol. Triac Driver		1.25

SOCKETS — Test TEXTOOL Sockets — RECEPTACLES

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* G.F. PSF Plastic Body
* For testing IC's

* Nickel Boron Plating
* G.F. PSF Plastic Body
* Wire Wrap Contacts

Part No.	Pins	Price	Part No.	Pins	Price
214-3339	14 pin	5.95	222-3343	22 pin	9.95
216-3340	16 pin	6.49	224-3344	24 pin	9.75
218-3341	18 pin	7.95	228-3345	28 pin	11.95
220-3342	20 pin	8.95	240-3346	40 pin	12.95

Part No.	Pins	Price	Part No.	Pins	Price
214-3592	14 pin	9.75	222-3596	22 pin	12.95
216-3593	16 pin	9.95	224-3597	24 pin	12.75
218-3594	18 pin	10.95	228-3598	28 pin	13.95
220-3595	20 pin	11.95	240-3599	40 pin	15.95

LOW PROFILE (TIN) SOCKETS

	1-24	25-49	50-100
8 pin LP	.17	.16	.15
14 pin LP	.20	.19	.18
16 pin LP	.22	.21	.20
18 pin LP	.29	.28	.27
20 pin LP	.34	.32	.30
22 pin LP	.37	.36	.35
24 pin LP	.38	.37	.36
28 pin LP	.45	.44	.43
36 pin LP	.60	.59	.58
40 pin LP	.63	.62	.61

SOLDERTAIL STANDARD (TIN)

	1-24	25-49	50-100
14 pin ST	.27	.25	.24
16 pin ST	.30	.27	.25
18 pin ST	.35	.32	.30
24 pin ST	.49	.45	.42
28 pin ST	.99	.90	.81
36 pin ST	1.39	1.26	1.15
40 pin ST	1.59	1.45	1.30

SOLDERTAIL (GOLD) STANDARD

	1-24	25-49	50-100
8 pin SG	.39	.35	.31
14 pin SG	.49	.45	.41
16 pin SG	.54	.49	.44
18 pin SG	.59	.53	.48
24 pin SG	.79	.75	.69
28 pin SG	1.10	1.00	.90
36 pin SG	1.65	1.40	1.26
40 pin SG	1.75	1.59	1.45

WIRE WRAP SOCKETS (GOLD) LEVEL #3

	1-24	25-49	50-100
8 pin WW	.59	.54	.49
10 pin WW	.69	.63	.58
14 pin WW	.79	.73	.67
16 pin WW	.85	.77	.70
18 pin WW	.99	.90	.81
20 pin WW	1.19	1.08	.99
22 pin WW	1.49	1.35	1.23
24 pin WW	1.39	1.26	1.14
28 pin WW	1.69	1.53	1.38
36 pin WW	2.19	1.99	1.79
40 pin WW	2.29	2.09	1.89

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ASST. 1	5ea.	10 Ohm 12 Ohm 15 Ohm 18 Ohm 22 Ohm / 27 Ohm 33 Ohm 39 Ohm 47 Ohm 56 Ohm	50pcs.	$1.95
ASST. 2	5ea.	68 Ohm 82 Ohm 100 Ohm 120 Ohm 150 Ohm / 180 Ohm 220 Ohm 270 Ohm 330 Ohm 390 Ohm	50pcs.	$1.95
ASST. 3	5ea.	470 Ohm 560 Ohm 680 Ohm 820 Ohm 1K / 1.2K 1.5K 1.8K 2.2K 2.7K	50pcs.	$1.95
ASST. 4	5ea.	3.3K 3.9K 4.7K 5.6K 6.8K / 8.2K 10K 12K 15K 18K	50pcs.	$1.95
ASST. 5	5ea.	22K 27K 33K 39K 47K / 56K 68K 82K 100K 120K	50pcs.	$1.95
ASST. 6	5ea.	150K 180K 220K 270K 330K / 390K 470K 560K 680K 820K	50pcs.	$1.95
ASST. 7	5ea.	1M 1.2M 1.5M 1.8M 2.2M / 2.7M 3.3M 3.9M 4.7M 5.6M	50pcs.	$1.95
ASST. 8R		Includes Resistor Assts. 1-7 (350 pcs.)		$10.95 ea.

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INTERSIL

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7045IPI	CMOS Precision Timer	14.95
7045EV/Kit*	Stopwatch Chip, XTL	24.95
7106CPL	3½ Digit A/D (LCD Drive)	16.95
7106EV/Kit*	IC, Circuit Board, Display	34.95
7107CPL	3½ Digit A/D (LED Drive)	15.95
7107EV/Kit*	IC, Circuit Board, Display	29.95
7116CPL	3½ Digit A/D LCD Dis. HLD.	18.95
7117CPL	3½ Digit A/D LED Dis. HLD.	17.95
7201IDR	Low Battery Volt Indicator	2.25
7205IPG	CMOS LED Stopwatch/Timer	12.95
7205EV/Kit*	Stopwatch Chip, XTL	19.95
7206CJPE	Tone Generator	5.15
7206CEV/Kit*	Tone Generator Chip, XTL	12.95
7207AIPD	Oscillator Controller	6.50
7207AEV/Kit*	Freq. Counter Chip, XTL	13.95
7208IPI	Seven Decade Counter	17.95
7209IPA	Clock Generator	3.95
7215IPG	4 Func. CMOS Stopwatch CKT	13.95
7215EV/Kit*	4 Func. Stopwatch Chip, XTL	19.95
7216AIJI	8-Digit Univ. Counter C.A.	32.00
7216CIJI	8-Digit Freq. Counter C.A.	26.95
7216DIPI	8-Digit Freq. Counter C.C.	21.95
7217IJI	4-Digit LED Up/Down Counter	12.95
7218CIJI	8-Digit Univ. LED Drive	10.95
7224IPL	LCD 4½ Digit Up Counter DRI	11.25
7226AIJL	8-Digit Univ. Counter	31.95
7226AEV/Kit*	5 Function Counter Chip, XTL	74.95
7240IJE	CMOS Bin Prog. Timer/Counter	4.95
7242IJA	CMOS Divide-by-256 RC Timer	2.05
7250IJE	CMOS BCD Prog. Timer/Counter	6.00
7260IJE	CMOS BCD Prog. Timer/Counter	5.25
7555IPA	CMOS 555 Timer (8 pin)	1.45
7556IPD	CMOS 556 Timer (14 pin)	2.20
7611BCPA	CMOS Op Amp Comparator 5MV	2.25
7612BCPA	CMOS Op Amp Ext. Cmvr. 5MV	2.95
7621BCPA	CMOS Dual Op Amp Comp. 5MV	3.95
7631CCPE	CMOS Tri Op Amp Comp. 10MV	5.35
7641CCPD	CMOS Quad Op Amp Comp. 10MV	7.50
7642CCPD	CMOS Quad Op Amp Comp. 10MV	7.50
7660CPA	Voltage Converter	2.95
8038CCPD	Waveform Generator	4.95
8048CCPE	Monolithic Logarithmic Amp	21.60
8069CCQ	50ppm Band—GAP Volt Ref. Diode	2.50
8211CPA	Volt Ref/Indicator	2.95
8212CPA	Volt Ref/Indicator	2.95

74C

Part	Price	Part	Price	Part	Price
74C00	.39	74C95	1.59	74C221	1.95
74C02	.39	74C107	1.89	74C240	2.25
74C04	.39	74C151	2.95	74C244	2.25
74C08	.39	74C154	3.95	74C373	2.49
74C10	.39	74C157	2.25	74C374	2.59
74C14	.75	74C160	1.69	74C901	.69
74C20	.39	74C161	1.60	74C903	.69
74C30	.39	74C162	1.49	74C911	10.95
74C42	1.39	74C163	1.69	74C912	10.95
74C48	1.95	74C164	1.59	74C915	1.69
74C73	.79	74C173	1.39	74C917	10.95
74C74	.79	74C174	1.39	74C922	5.49
74C85	1.95	74C175	1.19	74C923	5.75
74C86	.99	74C192	1.69	74C925	7.50
74C89	6.95	74C193	1.69	74C926	7.50
74C90	1.29	74C195	1.59	80C95	.79
74C93	1.29			80C97	.79

LINEAR

Part	Price	Part	Price	Part	Price
LH0002CN	6.85	LM340T-5	1.25	LM702H	.79
LM10CLH	4.50	LM340T-12	1.25	LM703CN	.89
LM11CLH	4.75	LM340T-15	1.25	LM709N	.29
LH0070-OH	4.55	LM341P-5	.75	LM710N	.79
TL071CP	.79	LM341P-12	.75	LM711N	.79
TL072CP	1.39	LM341P-15	.75	LM723N	.69
TL074CN	2.49	LM342P-5	.69	LM733N	1.00
LH0082CD	35.80	LM342P-12	.69	LM739N	1.19
TL082CP	1.19	LM342P-15	.69	LM741CN	.35
TL084CN	2.19	LM348N	1.25	MC1741SCG	3.00
LH0094CD	36.80	LM350K	5.75	LM747N	.79
LM300H	.99	LF351N	.60	LM748N	.59
LM301CN	.35	LF353N	1.00	LM1014N	2.75
LM302H	1.95	LF355N	1.10	LM1310N	1.95
LM304H	1.95	LF356N	1.10	LM1458CN	.59
LM305H	.99	LM358N	1.00	LM1488N	1.25
LM307CN	.45	LM359N	1.79	LM1489N	1.25
LM308CN	1.00	LM370N	4.49	LM1496N	1.95
LM309H	1.95	LM373N	3.25	LM1556V	1.75
LM309K	1.25	LM377N	2.95	LM1800N	2.95
LM310CN	1.75	LM380N	1.25	LM1871N	5.49
LM311/CN	.90	LM381N	1.95	LM1872N	5.49
LM312H	2.49	LM382N	1.79	LM1877N-9	3.25
LM317MP	1.15	LM384N	1.95	LM1889N	3.20
LM317T	1.75	LM386N-3	1.29	LM1896N	1.75
LM317K	3.95	LM387N	1.45	LM2002T	1.49
LM318CN	1.95	LM389N	1.35	LM2877P	2.05
LM319N	1.95	LM392N	.69	LM2878P	2.25
LM320K-5	1.35	LF398N	4.00	LM2896P-1	2.25
LM320K-12	1.35	LM399H	5.00	LM3189N	2.95
LM320K-15	1.35	TL494CN	4.49	LM3900N	.69
LM320T-5	1.25	TL496CP	1.75	LM3905CN	1.25
LM320T-12	1.25	NE510A	6.00	LM3909N	1.15
LM320T-15	1.25	NE529A	4.95	LM3914N	3.95
LM323K	5.95	NE531H	3.95	LM3915N	3.95
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LM329DZ	.65	NE540H	6.00	RC4136N	1.25
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LM334Z	1.30	NE550A	1.30	RC4194TK	6.95
LM335Z	1.40	NE555V	.39	RC4195TK	5.49
LM336Z	1.75	LM556N	.99	LM4500A	3.25
LM337T	1.95	NE564N	3.95	ICL8038B	4.95
LM337MP	1.15	LM565N	.99	LM13080N	1.29
LM338K	6.95	LM566CN	1.95	LM13600N	1.49
LM339N	.99	LM567V	1.25	75138N	1.95
LM340K-5	1.35	NE570N	4.95	75450N	.89
LM340K-12	1.35			75451CN	.39
LM340K-15	1.35			75492	.89

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50 VOLT CERAMIC DISC CAPACITORS

Value	1-9	10-99	100+	Value	1-9	10-99	100+
10 pf	.08	.06	.05	.001µF	.08	.06	.05
22 pf	.08	.06	.05	.0047µF	.08	.06	.05
47 pf	.08	.06	.05	.01µF	.08	.06	.05
100 pf	.08	.06	.05	.022µF	.09	.07	.06
220 pf	.08	.06	.05	.047µF	.09	.07	.06
470 pf	.08	.06	.05	.1µF	.15	.12	.10

100 VOLT MYLAR FILM CAPACITORS

.001mf	.12	.10	.07	.022mf	.13	.11	.08
.0022mf	.12	.10	.07	.047mf	.21	.17	.13
.0047mf	.12	.10	.07	.1mf	.27	.23	.17
.01mf	.12	.10	.07	.22mf	.33	.27	.22

+20% DIPPED TANTALUMS (Solid) CAPACITORS

.1/35V	.39	.34	.29	1.5/35V	.41	.37	.29
.15/35V	.39	.34	.29	2.2/35V	.51	.45	.34
.22/35V	.39	.34	.29	3.3/35V	.53	.47	.37
.33/35V	.39	.34	.29	4.7/25V	.63	.56	.45
.47/35V	.39	.34	.29	6.8/25V	.79	.69	.55
.68/35V	.39	.34	.29	15/25V	1.39	1.25	.95
1.0/35V	.39	.34	.29	22/6V	.79	.69	.55

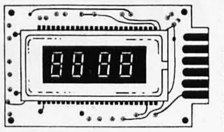
MINI. ALUMINUM ELECTROLYTIC CAPACITORS

Axial	1-99	100-499	500+	Radial	1-99	100-499	500+
.47/50V	.16	.14	.10	.47/25V	.15	.13	.12
1.0/50V	.16	.14	.12	.47/50V	.16	.14	.13
3.3/50V	.16	.15	.11	1.0/16V	.15	.13	.12
4.7/25V	.16	.15	.11	1.0/25V	.16	.14	.13
10/25V	.16	.15	.11	1.0/50V	.17	.15	.14
10/50V	.19	.16	.12	4.7/16V	.15	.13	.12
22/25V	.19	.16	.12	4.7/25V	.16	.14	.13
22/50V	.24	.20	.18	4.7/50V	.17	.15	.14
47/25V	.25	.21	.19	10/16V	.15	.13	.12
47/50V	.29	.25	.23	10/25V	.16	.14	.13
100/25V	.28	.24	.22	10/50V	.17	.15	.14
100/50V	.41	.37	.34	47/50V	.25	.21	.19
220/25V	.39	.34	.33	100/16V	.21	.17	.14
220/50V	.49	.45	.41	100/25V	.25	.23	.21
470/25V	.54	.49	.45	100/50V	.37	.34	.31
1000/16V	.79	.69	.61	220/16V	.25	.21	.19
2200/16V	.89	.79	.69	470/25V	.35	.31	.27

Circle 180 on inquiry card.

National Semiconductor

Clock Modules



12VDC AUTOMOTIVE/ INSTRUMENT CLOCK

APPLICATIONS:
- In-dash autoclocks
- After-market auto/ RV clocks
- Aircraft-marine clks.
- 12VDC oper. instru.
- Portable/battery powered instrumnts.

Features: Bright 0.3" green display. Internal crystal time-base. ± 0.5 sec./day accur. Auto. display brightness control logic. Display color filterable to blue, blue-green, green & yellow. Complete—just add switches and lens.

MA1003 Module (3.05"L×1.75"H×.98"D) . **$16.95**

CLOCK MODULES

MA1023	.7" Red Digital LED Clock Module	8.95
MA1026	.7" Dig. LED Alarm Clock/Thermometer	18.95
MA5036	.3" Red Digital LED Clock/Timer	6.95
MA1002	.5" Red Digital LED Clock & Xformer	9.95
MA1010	.8" Red Digital LED Clock	7.95
MA1032	CBA .5" Red Digital LCD Clock	17.95
MA1043	.7" Green Digital LED Clock	8.95

TRANSFORMERS

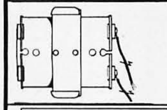
102-P20	Xformer for MA1023, 1043 & 5036 Mods.	3.49
102-P22	Xformer for MA1026 Clock Modules	3.49
102-P24	Xformer for MA1010 Clock Modules	3.49

8 OHM SPEAKER

2¼" – 8 Ohm – .25 watt

A0201

$1.25 ea. 2/$1.95 ea. 10/$7.95 ea.

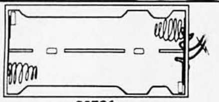


BATTERY HOLDER

- Holds 2 ea. C cells
- Aluminum Case
- 5" leads

H-801-159

$ .45 each 10/$3.95



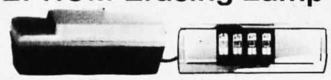
BATTERY HOLDER

- Holds 4 ea. C cells
- Plastic case
- 9" leads

82721

$ .49 ea. 10/$4.25

EPROM Erasing Lamp



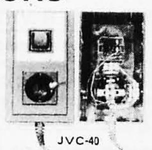
- Erases 2708, 2716, 1702A, 5203Q, 5204Q, etc.
- Erases up to 4 chips within 20 minutes.
- Maintains constant exposure distance of one inch.
- Special conductive foam liner eliminates static build-up.
- Built-in safety lock to prevent UV exposure.
- Compact – only 7-5/8" × 2-7/8" × 2"
- Complete with holding tray for 4 chips.

UVS-11EL Replacement Bulb $16.95

UVS-11E $79.95

JOYSTICKS

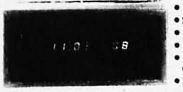
JS-5K



JVC-40

JS-5K	5K Linear Taper Pots	$5.25
JS-100K	100K Linear Taper Pots	$4.95
JVC-40	40K (2) Video Controller in case . . .	$4.95

6-Digit Clock Kit



- Bright .300 ht. comm. cathode display
- Uses MM5314 clock chip
- Switches for hours, minutes and hold modes
- Hrs. easily viewable to 20 ft.
- Simulated walnut case
- 115 VAC operation
- 12 or 24 hr. operation
- Incl. all components, case & wall transformer
- Size: 6¾" × 3-1/8" × 1¾"

JE701 . . . . $19.95

NEW!

JE215 Adjustable Dual Power Supply

General Description: The JE215 is a Dual Power Supply with independent adjustable positive and negative output voltages. A separate adjustment for each of the supplies provides the user unlimited applications for IC current voltage requirements. The supply can also be used as a general all-purpose variable power supply.

FEATURES:
- Adjustable regulated power supplies, pos. and neg. 1.2VDC to 15VDC.
- Power Output (each supply): 5VDC @ 500mA, 10VDC @ 750mA, 12VDC @ 500mA, and 15VDC @ 175mA.
- Two, 3-terminal adj. IC regulators with thermal overload protection.
- Heat sink regulator cooling
- LED "on" indicator
- Printed Board Construction
- 120VAC input
- Size: 3-1/2"w × 5-1/16"L × 2"H

JE215 Adj. Dual Power Supply Kit (as shown) . . $24.95

(Picture not shown but similar in construction to above)

JE200	Reg. Power Supply Kit (5VDC, 1 amp) . .	$14.95
JE205	Adapter Brd. (to JE200) ±5, ±9 & ±12V.	$12.95
JE210	Var. Pwr. Sply. Kit, 5-15VDC, to 1.5amp.	$19.95

MICROPROCESSOR COMPONENTS

8080A/8080A SUPPORT DEVICES

INS8080A	CPU	4.95
DP8212	8-Bit Input/Output	3.25
DP8214	Priority Interrupt Control	5.95
DP8216	Bi-Directional Bus Driver	3.49
DP8224	Clock Generator/Driver	3.95
DP8226	Bus Driver	3.49
DP8228	System Controller/Bus Driver	4.95
DP8238	System Controller	5.95
INS8243	I/O Expander for 48 Series	9.95
INS8250	Asynchronous Comm. Element	16.95
DP8251	Prog. Comm. I/O (USART)	7.95
DP8253	Prog. Interval Timer	14.95
DP8255	Prog. Peripheral I/O (PPI)	9.95
DP8257	Prog. DMA Control	19.95
DP8259	Prog. Interrupt Control	14.95
DP8275	Prog. CRT Controller	39.95
DP8279	Prog. Keyboard/Display Interface	19.95
DP8303	System Timing Element	6.95
DP8304	8-Bit Bi-Directional Receiver	3.95
DP8307	8-Bit Bi-Directional Receiver	3.95
DP8308	8-Bit Bi-Directional Receiver	3.95
DP8310	Octal Latched Peripheral Driver	5.25
DP8311	Octal Latched Peripheral Driver	5.25

6800/6800 SUPPORT DEVICES

MC6800	MPU	7.95
MC6802CP	MPU with Clock and RAM	14.95
MC6810API	128x8 Static RAM	4.95
MC6821	Peripheral Inter. Adapt (MC6820)	7.49
MC6828	Priority Interrupt Controller	10.95
MC6830L8	1024x8-Bit ROM (MC68A30-8)	14.95
MC6850	Asynchronous Comm. Adapter	6.95
MC6852	Synchronous Serial Data Adapter	6.95
MC6860	0-600bps Digital MODEM	10.95
MC6862	2400bps Modulator	12.95
MC6880A	Quad 3-State Bus. Trans. (MC8T26)	2.25

MICROPROCESSOR CHIPS

Z80 (780C)	CPU (MK3880N) (2MHz)	13.95
Z80A (780-1)	CPU (MK3880N-4) (4MHz)	15.95
CDP1802	CPU	19.95
2650	MPU	16.95
IDM2901ADC	CPU—4-Bit Slice (Com. Temp. Grade)	19.95
MCS6502	MPU w/Clock (65K Bytes Memory)	11.95
INS8035N-6	MPU—8-Bit (6MHz)	9.95
INS8039N-6	CPU—Sgl. Chip 8-Bit (128 bytes RAM)	19.95
INS8040N-6	CPU (256 Bytes RAM)	24.95
INS8070N	CPU—64 Bytes RAM	24.95
INS8073N	CPU w/Basic Micro Interpreter	29.95
P8085	CPU	19.95
TMS9900JL	MPU—16-Bit	49.95

SHIFT REGISTERS

MM500H	Dual 25-Bit Dynamic	.50
MM503H	Dual 50-Bit Dynamic	.50
MM506H	Dual 100-Bit Static	.50
MM510H	Dual 64-Bit Accumulator	.50
MM1402N	256-Bit Dynamic	2.95
MM5013N	1024-Bit Dynamic/Accumulator	1.95
MM5016H	500/512-Bit Dynamic	1.95
MM5034N	Octal 80-Bit	9.95
MM5035N	Octal 80-Bit	9.95
2504V (1404A)	1024-Bit Dynamic	1.95
2518N	Hex 32-Bit Static	3.95
2522V	Dual 132-Bit Static	2.95
2524V	512-Bit Dynamic	.99
2525V	1024-Bit Dynamic	2.95
2528V	Dual 250-Bit Static	3.95
2529V	Dual 240-Bit Static	3.95
2532N	Quad 80-Bit Static	2.95
3341PC	Fifo (Dual 80)	6.95

DATA ACQUISITION

AF100-1CN	Universal Active Filter 2.5%	5.95
AF121-1CJ	Touch Tone Low Band Filter	19.95
AF122-1CJ	Touch Tone High Band Filter	19.95
LM308AH	Super Gain Op Amp	1.15
LM334Z	Constant Current Source	1.30
LM335Z	Temperature Transducer	1.40
LF356N	JFET Input Op Amp	1.10
LF398N	Sample & Hold Amplifiers	3.95
LM399H	Temp. Comp. Prec. Ref. (.5ppm/C°)	4.95
ADC0804LCN	8-Bit A/D Converter (1 LSB)	4.95
DAC0806LCN	8-Bit D/A Converter (0.78% Lin.)	2.25

DATA ACQUISITION (CONTINUED)

ADC0809CCN	8-Bit A/D Converter (8-Ch. Multi.)	5.25
ADC0817CCN	8-Bit A/D Converter (16-Ch. Multi.)	10.95
DAC1000LCN	10-Bit D/A Conv. Micro. Comp. (0.05%)	13.95
DAC1008LCN	10-Bit D/A Conv. Micro. Comp. (0.20%)	8.95
DAC1020LCN	10-Bit D/A Converter (0.05% Lin.)	8.49
DAC1022LCN	10-Bit D/A Converter (0.20% Lin.)	5.95
DAC1222LCN	12-Bit D/A Converter (0.20% Lin.)	9.95
CD4051N	8-Channel Multiplexer	1.19
AY-5-1013	30K BAUD UART	6.95

RAM'S

1101	256x1 Static	1.49
1103	1024x1 Dynamic	.99
2101 (8101)	256x4 Static	3.95
2102	1024x1 Static	1.75
21L02	1024x1 Static	1.95
2111 (8111)	256x4 Static	3.95
2112	256x4 Static MOS	4.95
2114	1024x4 Static 450ns	3.25
2114L	1024x4 Static 450ns Low Power	3.49
2114-2	1024x4 Static 200ns	3.95
2114L-2	1024x4 Static 200ns Low Power	4.95
74S200	256x1 Static	6.95
4116N-4 (UPD416)	16K Dynamic 250ns (MM5290N-4)	3.49
4164	64K Dynamic 250ns	19.95
MM2147J	4096x1 Fast 70ns	7.95
5101	256x4 Static	7.95
MM5261	1024x1 Dynamic Fully Decoded	.99
MM5262	2Kx1 Dynamic	.49
MM5280/2107	4096x1 Dynamic	4.95
MM5290N-2 (4116)	16K Dynamic 150ns (UPD416C-3)	4.49
MM5298J-3A	8K Dyn. 200ns (lower ½ of MM5290J)	1.95
82S25	64 Bit RAM (16x4)	3.49
UPD414/MK4027	4K Dynamic 16-pin	4.95
TMS4044-45NL	4K Static	9.95
TMS4045	1024x4 Static	9.95

PROMS/EPROMS

1702A	2K UV Erasable PROM	6.95
2708	8K EPROM	4.95
TMS2716	16K EPROM (-5V, +5V, +12V)	19.95
2716 Intel (2516) TI	16K EPROM (Single +5V)	8.95
2732 Intel TI	32K EPROM	17.95
2758	8K EPROM (450ns) (Single +5V)	7.49
2764Q	64K EPROM	99.95
5203	2048 PROM	14.95
82S23(74S188)	32x8 PROM (Open Collector)	3.95
82S115	4096 Bipolar PROM	14.95
82S123(74S288)	32x8 Tri-State Bipolar PROM	3.95
82S185	8K PROM	19.95

— Over 30 More PROMS Listed in Our Catalog —

ROM'S

2513(2140)	Character Generator (Upper Case)	9.95
2513(3021)	Character Generator (Lower Case)	9.95

NMOS READ ONLY MEMORIES

MCM66710P	128x9x7 ASCII Shifted w/Greek	13.50
MCM66740P	128x9x7 Math Symbol & Pictures	13.50
MCM66750P	128x9x7 Alpha. Control Char. Gen.	13.50

MICROPROCESSOR MANUALS

M-Z80	User Manual	7.50
M-CDP1802	User Manual	7.50
M-2650	User Manual	5.00

SPECIAL FUNCTION

DS0025CN	Dual MOS Clock Driver (5MZ)	3.50
DS0026CN	Dual MOS Clock Driver (5MZ)	1.95
INS1771N-1	Floppy Disc Controller	24.95
INS2651N	Communication Chip	19.95
MM58167N	Microprocessor Real Time Clock	8.95
MM58174N	Microprocessor Compatible Clock	11.95
COP402N	Microcontroller with 64-Digit RAM and Direct LED Drive	6.95
COP402MN	Microcontroller with 64-Digit RAM & Direct LED Drive w/N Buss Int.	7.49
COP470N	32-Seg. VAC Fluor. Driver (20-pin pkg.)	3.25

TELEPHONE/KEYBOARD CHIPS

AY-5-9100	Push Button Telephone Dialer	14.95
AY-5-9200	Repertory Dialer	14.95
AY-5-9500	CMOS Clock Generator	4.95
AY-5-2376	Keyboard Encoder (88 keys)	11.95
HD0165-5	Keyboard Encoder (16 keys)	7.95
74C922	Keyboard Encoder (16 keys)	5.49
74C923	Keyboard Encoder (20 keys)	5.75
MM53190N	Push Button Pulse Dialer	7.95
MM57499N	96/144-Key Serial Keyboard Encoder	8.95

ELECTRONIC TOY MOTORS

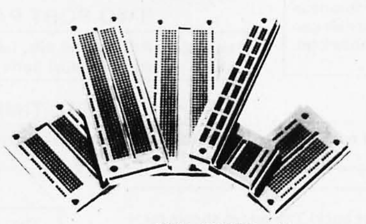
Typical Power Source	Operating Voltage Range	Voltage	TYPICAL CHARACTERISTICS: NO LOAD Speed RPM	NO LOAD Current AMP	AT MAXIMUM EFFICIENCY Speed RPM	AT MAXIMUM EFFICIENCY Current AMP	AT MAXIMUM EFFICIENCY Torque OZ. IN.	AT MAXIMUM EFFICIENCY Output W	AT MAXIMUM EFFICIENCY Eff. %	SMALL TORQUE OZ. IN.
DRY CELL	1.5-6.0	3.0	9,200	0.20	6,750	0.90	0.260	1.30	57.0	0.97

.937 O.D. X 1.201 Length

MABUCHI RE280 $ .99 each . . . 10/$7.50 . . . 100/$50.00

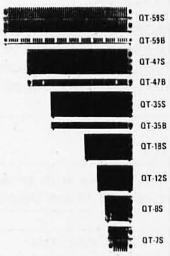
GLOBAL SPECIALTIES

EXPERIMENTOR SOCKETS



Model	Length	Width	Center Channel	5 Tie Point Terminals	Bus Strips	Price
EXP4B	6.0"	1.0"	n/a	n/a	4(160)	$ 4.75
EXP300	6.0"	2.1"	.3"	94(470)	2(80)	$12.00
EXP325	1.8"	2.1"	.3"	22(110)	2(20)	$ 3.50
EXP350	3.6"	2.1"	.3"	46(230)	2(40)	$ 6.75
EXP600	6.0"	2.4"	.6"	94(470)	2(80)	$14.75
EXP650	3.6"	2.4"	.6"	46(230)	2(40)	$ 8.75

Quick Test Sockets & Bus Strips



	Length	Hole to-hole	Terminals	Unit Price $
QT-59S	6.5"	6.2"	118	$12.50
QT-59B	6.5"	6.2"	20	$ 2.99
QT-47S	5.3"	5.0"	94	$10.24
QT-47B	5.3"	5.0"	16	$ 2.59
QT-35S	4.1"	3.8"	70	$ 8.50
QT-35B	4.1"	3.8"	12	$ 2.25
QT-18S	2.4"	2.1"	36	$ 4.50
QT-12S	1.8"	1.5"	24	$ 3.75
QT-8S	1.4"	1.1"	16	$ 3.00
QT-7S	1.3"	1.0"	14	$ 2.75

$10.00 Min. Order – U.S. Funds Only
Calif. Residents Add 6% Sales Tax
Postage – Add 5% plus $1 Insurance

Spec Sheets — 25¢
Send 86¢ Postage for your
FREE 1982 JAMECO CATALOG

NEW 1982 CATALOG

Jameco ELECTRONICS

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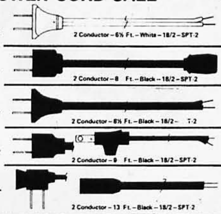
9/81

POWER CORD SALE



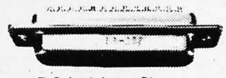
Part	1-9	10-99	100
842-812	.35	.30	.25
362-812	.39	.35	.30
473-862	.45	.39	.35
468-828	.49	.45	.39
435-802	.59	.55	.49

AC and DC Wall Transformers

Ideal for use with clocks, games, power supplies or any other type of AC or DC application.

Part No.	Input	Output	Price
AC 250	117V/60Hz	12 VAC 250mA	$3.95
AC 500	117V/60Hz	12 VAC 500mA	$4.95
AC1000	117V/60Hz	12 VAC 1 amp	$5.95
AC1700	117V/60Hz	9 VAC 1.7 amp	$3.95
DV 9200	117V/60Hz	9 VDC 200mA	$3.25
DC 900	120V/60Hz	9 VDC 500mA	$3.95

CONNECTORS



DB25P	D-Subminiature Plug	$2.95
DB25S	D-Subminiature Socket	$3.50
D20418-2	Screw Lock Hdwr. (2) DB25S/P	$ .49
DB51226	Cover for DB25P/S	$1.75
22/44SE	P.C. Edge (22/44 Pin)	$2.95
UG88/U	BNC Plug	$1.79
UG89/U	BNC Jack	$3.79
UG175/U	UHF Adapter	$ .49
SO239	UHF Panel Recp.	$1.29
PL258	UHF Adapter	$1.60
PL259	UHF Plug	$1.60
UG260/U	BNC Plug	$1.79
UG1094/U	BNC Bulkhead Recp.	$1.29

TRS-80 16K Conversion Kit

Expand your 4K TRS-80 System to 16K.
Kit comes complete with:
★ 8 ea. MM5290 (UPD416/4116) 16K Dyn. Rams (*NS)
★ Documentation for Conversion

TRS-16K2 *150NS **$29.95**
TRS-16K4 *250NS **$24.95**

JE610 ASCII Encoded Keyboard Kit

The JE610 ASCII Keyboard Kit can be interfaced into most any computer system. The kit comes complete with an industrial grade keyboard switch assembly (62-keys), IC's, sockets, connector, electronic components and a double-sided printed wiring board. The keyboard assembly requires +5V @ 150mA and −12V @ 10 mA for operation. Features: 60 keys generate the 126 characters, upper and lower case ASCII set. Fully buffered. Two user-define keys provided for custom applications. Caps lock for upper-case-only alpha characters. Utilizes a 2376 (40-pin) encoder read-only memory chip. Outputs directly compatible with TTL/DTL or MOS logic arrays. Easy interfacing with a 16-pin dip or 18-pin edge connector. Size: 3½"H × 14½"W × 8¾"D

JE610/DTE-AK (After assembled as pictured above) . . . **$124.95**

JE610 Kit 62-Key Keyboard, PC Board, & Components (no case). . . . **$ 79.95**

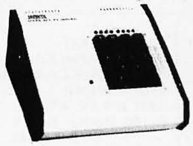
K62 62-Key Keyboard (Keyboard only) . . . . **$ 34.95**

DTE-AK (case only – 3¼"H×11"W×8¾"D) **$ 49.95**

NEW!

JE212 – Negative 12VDC Adapter Board Kit for JE610 ASCII KEYBOARD KIT
Provides -12VDC from incoming 5VDC . . $9.95

JE600 Hexadecimal Encoder Kit



FULL 8-BIT LATCHED OUTPUT 19-KEY KEYBOARD

The JE600 Encoder Keyboard Kit provides two separate hexadecimal digits produced from sequential key entries to allow direct programming for 8-bit microprocessor or 8-bit memory circuits. Three additional keys are provided for user operations with one having a bistable output available. The outputs are latched and monitored with 9 LED readouts. Also included is a key entry strobe. Features: Full 8-bit latched output for microprocessor use. Three user-define keys with one being bistable operation. Debounce circuit provided for all 19 keys. 9 LED readouts to verify entries. Easy interfacing with standard 16-pin IC connector. Only +5VDC required for operation. Size: 3½"H × 8¼"W × 8¾"D

JE600/DTE-HK (After assembled as pictured above) **$99.95**

JE600 Kit 19-Key Hexadec. Keyboard, PC Board & Cmpnts. (no case) . . **$59.95**

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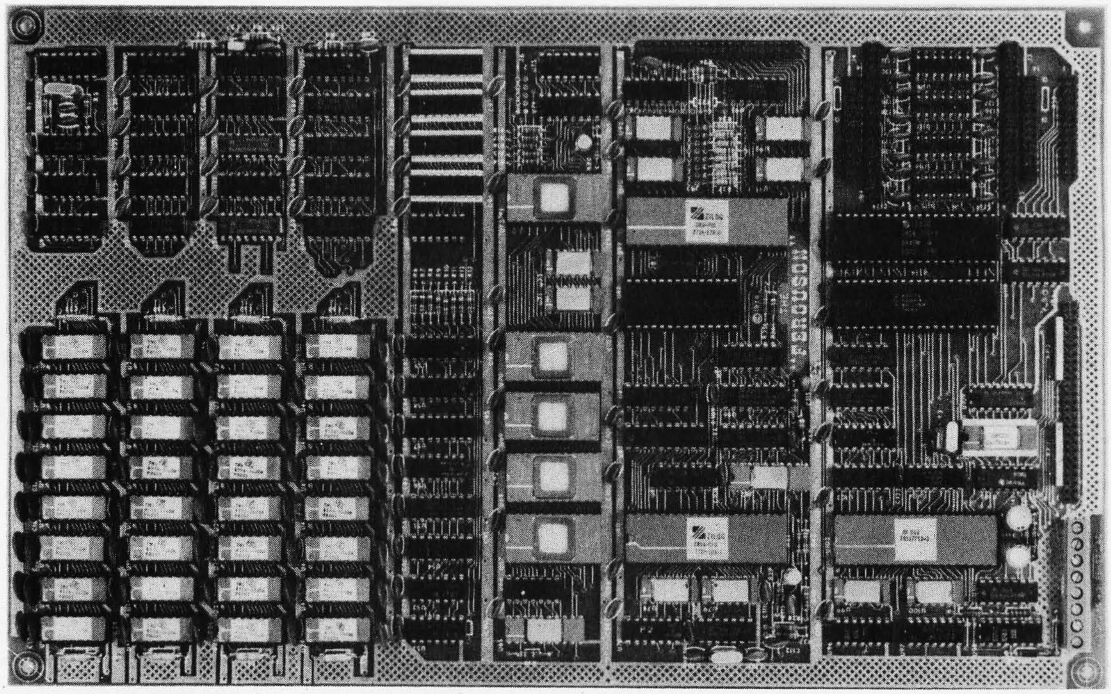
Z-80 CPU! 64K RAM!



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And Soldered Add $50.

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$649.00** (64K KIT BASIC I/O)

SIZE: 8½ x 13¾ IN.
SAME AS AN 8 IN. DRIVE.
REQUIRES: +5V @ 3 AMPS
+ - 12V @ .5 AMPS.

FULLY SOCKETED!

FEATURES: (Remember, all this on one board!)

64K RAM

Uses industry standard 4116 RAM'S. All 64K is available to the user, our VIDEO and EPROM sections do not make holes in system RAM. Also, very special care was taken in the RAM array PC layout to eliminate potential noise and glitches.

Z-80 CPU

Running at 2.5 MHZ. Handles all 4116 RAM refresh and supports Mode 2 INTERUPTS. Fully buffered and runs 8080 software.

SERIAL I/O (OPTIONAL)

Full 2 channels using the Z80 SIO and the SMC 8116 Baud Rate Generator. FULL RS232! For synchronous or asynchronous communication. In synchronous mode, the clocks can be transmitted or received by a modem. Both channels can be set up for either data-communication or data-terminals. Supports mode 2 Int. Price for all parts and connectors: $85.

BASIC I/O

Consists of a separate parallel port (Z80 PIO) for use with an ASCII encoded keyboard for input. Output would be on the 80 x 24 Video Display.

24 x 80 CHARACTER VIDEO

With a crisp, flicker-free display that looks extremely sharp even on small monitors. Hardware scroll and full cursor control. Composite video or split video and sync. Character set is supplied on a 2716 style ROM, making customized fonts easy. Sync pulses can be any desired length or polarity. Video may be inverted or true. 5 x 7 Matrix - Upper & Lower Case

FLOPPY DISC CONTROLLER

Uses WD1771 controller chip with a TTL Data Separator for enhanced reliability. IBM 3740 compatible. Supports up to four 8 inch disc drives. Directly compatible with standard Shugart drives such as the SA800 or SA801. Drives can be configured for remote AC off-on. Runs CP/M* 2.2.

TWO PORT PARALLEL I/O (OPTIONAL)

Uses Z-80 PIO. Full 16 bits, fully buffered, bi-directional. User selectable hand shake polarity. Set of all parts and connectors for parallel I/O: $29.95

REAL TIME CLOCK (OPTIONAL)

Uses Z-80 CTC. Can be configured as a Counter on Real Time Clock. Set of all parts: $14.95

SYSTEM COMPARISON

64K RAM KIT	$370.00
80 x 24 Video Kit	365.00
Floppy Disk Controller Kit	235.00
Z-80 CPU Kit	185.95
SER & PAR. I/O	129.95
S-100 Mother Board	45.00
SUB TOTAL	$1330.90

Talk about bangs per buck! The prices shown for S100 kits were taken from the July 1980 BYTE. This will give some basis for comparison between the Big Board and a similar system implementation on the S100 Buss.

CP/M* 2.2 FOR BIG BOARD

The popular CP/M* D.O.S. modified by MICRONIX SYSTEMS to run on Big Board is available for $150.00.

PC BOARD

Blank PC Board with Rom Set and Full Documentation. $199.00

PFM 3.0 2K SYSTEM MONITOR

The real power of the Big Board lies in its PFM 3.0 on board monitor. PFM commands include: Dump Memory, Boot CP/M*, Copy, Examine, Fill Memory, Test Memory, Go To, Read and Write I/O Ports, Disc Read (Drive, Track, Sector), and Search. PFM occupies one of the four 2716 EPROM locations provided.

Z-80 is a Trademark of Zilog.

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TERMS: Shipments will be made approximately 3 to 6 weeks after we receive your order. VISA, MC, cash accepted. We will accept COD's (for the Big Board only) with a $75 deposit. Balance UPS COD. Add $3.00 shipping.

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32K S-100 EPROM CARD
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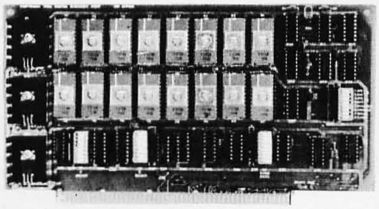


$79.95
KIT

USES 2716's

Blank PC Board - $34

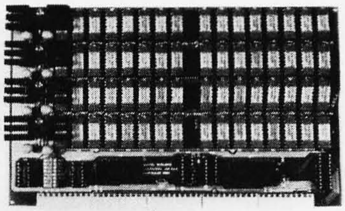
ASSEMBLED & TESTED ADD $30

SPECIAL: 2716 EPROM's (450 NS) Are $9.95 Ea. With Above Kit.

KIT FEATURES:
1. Uses +5V only 2716 (2Kx8) EPROM's.
2. Allows up to 32K of software on line!
3. IEEE S-100 Compatible.
4. Addressable as two independent 16K blocks.
5. Cromemco extended or Northstar bank select.
6. On board wait state circuitry if needed.
7. Any or all EPROM locations can be disabled.
8. Double sided PC board, solder-masked, silk-screened.
9. Gold plated contact fingers.
10. Unselected EPROM's automatically powered down for low power.
11. Fully buffered and bypassed.
12. Easy and quick to assemble.

32K SS-50 RAM

$299.00 KIT



For 2MHZ Add $10

Blank PC Board $50

For SWTPC 6800 - 6809 Buss

Support IC's and Caps $19.95

Complete Socket Set $21.00

Fully Assembled, Tested, Burned In Add $30

At Last! An affordable 32K Static RAM with full 6809 Capability.

FEATURES:
1. **Uses proven low power 2114 Static RAMS.**
2. **Supports SS50C - EXTENDED ADDRESSING.**
3. **All parts and sockets included.**
4. **Dip Switch address select as a 32K block.**
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16K STATIC RAM KIT-S 100 BUSS

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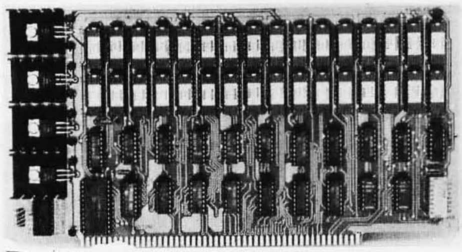

KIT FEATURES:
1. Addressable as four separate 4K Blocks.
2. ON BOARD BANK SELECT circuitry. (Cromemco Standard!). Allows up to 512K on line!
3. Uses 2114 (450NS) 4K Static Rams.
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16K STATIC RAM SS-50 BUSS

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$159 KIT

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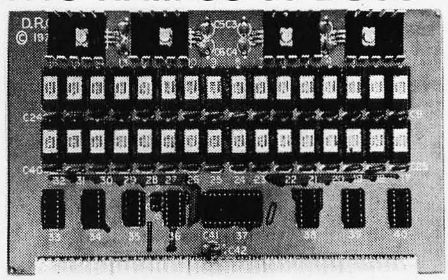

FOR SWTPC 6800 BUSS!

ASSEMBLED AND TESTED - $35

KIT FEATURES:
1. Addressable on 16K Boundaries
2. Uses 2114 Static Ram
3. Fully Bypassed
4. Double sided PC Board. Solder mask and silk screened layout
5. All Parts and Sockets included
6. Low Power: Under 1.5 Amps Typical

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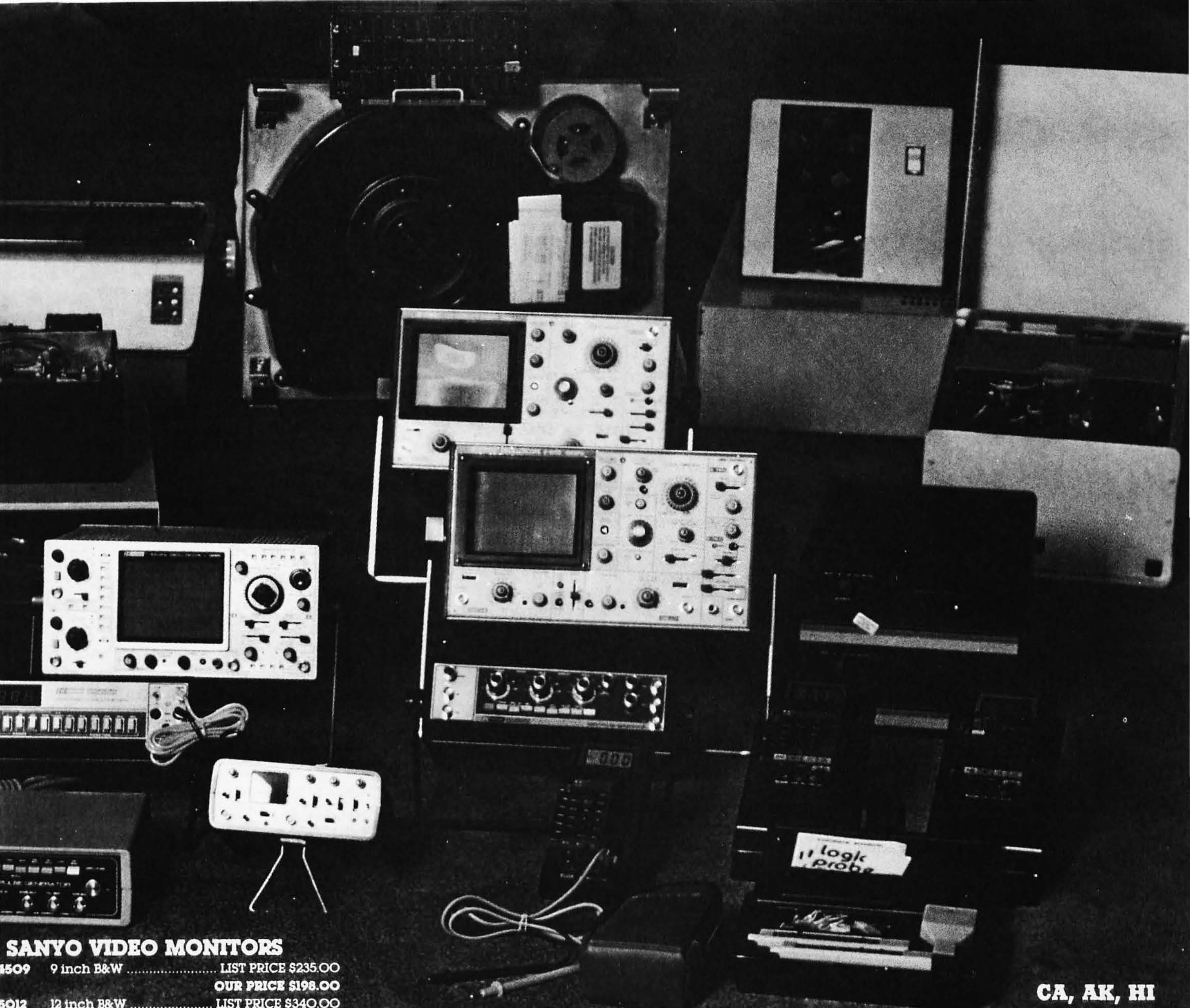

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4 MHZ, Bank select, 8/16 bit data

CCS-2032	A&T 32K	$599.00

16K STATIC RAM - GODBOUT
RAM 14, 10 MHZ, 24 bit addressing

GBT-143A	A&T 16K	$169.00
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16K STATIC RAM - CCS
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CCS-2116A	A&T 16K	$299.00

8K STATIC RAM - GODBOUT
Econoram II 2MHZ, 8K, No doubt, the most popular S-100 RAM ever built.

GBT-114U	UnKit 8K	$99.95

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programs 2708 or 2716's, operates as a 4K/8K EPROM board as well.

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ECONOROM 2708 - GODBOUT
16K x 8 EPROM Board using 2708, Power on jump to any 256 byte

GBT 125U	UnKit	$85.00
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DMA, Soft Sector, Controls 8" or 5¼", single or double density

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GBT 171C	CSC	$555.00
GBT CPM80	CP/M 2.2 for Z80/8085 with Manuals & BIOS 8" S.D. disk	$175.00
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CCS-2422	A&T with CPM 2.2 8" S.D.	$365.00

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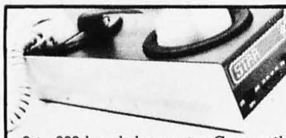

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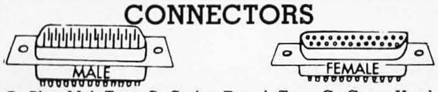

P=Plug, Male Type - S= Socket, Female Type - C= Cover, Hood

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CND-DA15C	15 pin cover	$ 1.50	$ 1.30	$ 1.10
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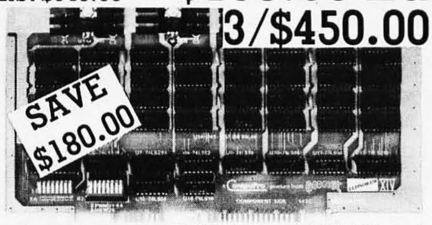

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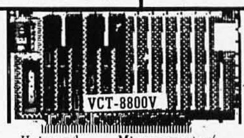

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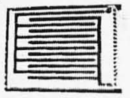

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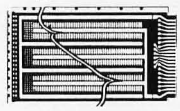

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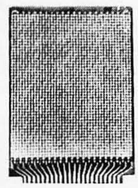

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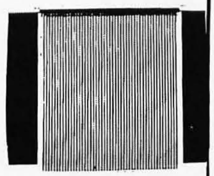

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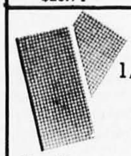

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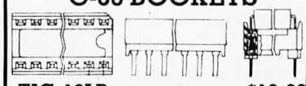

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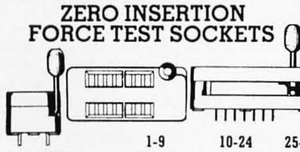

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ZIP-24DIP	$ 7.50	$7.25	$6.95
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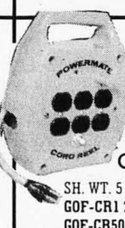

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FOR SALE: Netronics ELF II microcomputer with 8 K programmable memory, RS-232 interface, cassette-tape interface, Netronics video terminal, Motorola video monitor, Tiny BASIC on cassette, and full documentation. $400 (price negotiable). Mike Heitmann, 114 S Overbrook, St Charles MO 63301, (314) 723-3950 weekends or after 4:30 weekdays.

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FOR SALE: Decitek paper-tape reader. Easily runs at 600 cps. 7-inch rack mount. Complete power supply, parallel interface, and documentation. $200 or best offer. Tom Lock, 375 Front St, Box B-12, Berea OH 44017, (216) 234-2798.

FOR SALE: Set of 8 K Microsoft BASIC ROMs for Netronics Explorer-85 computer. All documentation included; $60. Wameco MEM-1A 8 K S-100 bus static memory with 300 ns low-power programmable memories; $75. Pat Taylor, 1200 S Market St, Bloomsburg PA 17815, (717) 784-6173.

FOR SALE: PET/CBM 2001 with 16 K programmable memory plus Skyles Toolkit read-only memory to debug BASIC programs. About one year old. $650 FOB. Many PET programs included. Also, Divert-A-Matic phone-call diverter. SASE for description. $150. Consider exchange for tape answerer. P Young, 1496 Cherrywood Dr, San Mateo CA 94403, (415) 574-4212 or 349-4325.

FOR SALE: SIM-1 microcomputer with 1 K programmable memory, expandable to 4 K and 51 I/O lines. $135. Mike Underwood, Rte 3 Box A-594, Troutville VA 24175, (703) 977-4337.

FOR SALE: Litton 1241-1251 with Multiplexer General Ledger, Payroll, Amortization, Depreciation Software, supplies, etc. Best offer. Alan Phelps, 1664 McDade Est, Conroe TX 77304, (713) 756-8889.

WANTED: The United States Yacht Racing Union is developing a Race Management Manual for use by race committees. A section will be devoted to computer and calculator programs. We are seeking programs related to sailing, race scoring, handicapping, measurement rules, etc. A library of these programs is being maintained. A listing of the programs available will be included in the manual. United States Yacht Racing Union, POB 209, Newport RI 02840.

FOR SALE: Godbout Interfacer I 2S; $200, CSI Qume Sprint 3 interfacer with 16 K buffer; $450, Jade Big Z Z80 processor card; $150, Printrol Qume Sprint 3 interface card; $75, Spellbinder word-processing program; $300. All items in excellent condition with manuals. Kirby Nickell, 2844 Angelique, St Joseph MO 64501.

FOR SALE: BYTE from January 1977 thru August 1977 and March 1981. $21, best offer, or trade for the following BYTEs: September 1975 thru October 1976, February 1980, September 1980, October 1980, or January 1981. Mark D Ybarra, 2604 Bobolink Dr, San Jose CA 95125, (408) 264-7789.

WANTED: Cartridges for Video Brain computer. Also need instructions for Finance cartridge. Particularly interested in Wordwise 2 cartridge and any schematic information. James Kasperski, 23-01 30 Dr, Long Island City NY 11102.

FOR SALE: Zenith/Heath H-11 system, 64 K programmable memory, two 8-inch floppy-disk drives, HT-11, and Pascal software. Fully DEC PDP-11/03 compatible. $4200. K W Scholz, 8216 Pickering St, Philadelphia PA 19150, (215) 248-0439 evenings.

FOR SALE: Heath H-8 computer. Assembled and tested, with manual. Will sell for best offer. David Wong, 1916 Grand Conc, New York NY 10457, (212) 294-8087.

FOR SALE: TI-810 printer with full ASCII uppercase and lowercase, floor stand, paper catch, and ribbons. $1100. HP-2321P interactive video terminal with built-in printer. $2100. Both items purchased for a remote station, but never used and are in brand-new condition. James Leonard, 58 Beverly Dr, Columbiana OH 44408, (216) 482-2291.

FOR SALE: 32 K Exidy Sorcerer, BASIC and Assembler ROMPACs plus Extended Cassette BASIC, RS-232, parallel, dual-cassette control. All documentation plus internal hardware and software manuals. Over $450 worth of software (graphics, games, word processing, data base, utilities, etc). All in excellent condition for $1250 or best offer. With Comprint printer, add $500. With 12-inch monitor, add $75. R L Henne, 5870 Wood Flower, Burke VA 22015, (703) 250-5323.

FOR SALE: IMSAI 8080 microcomputer with 48 K memory. Processor Technology boards included are: 3P+S I/O, CUTS cassette, GPM, VDM-1, and ALS-8 chip set (4 chips). Cromemco boards included are: TV Dazzler, ZPU processor, and 8 K Bytesaver. Miscellaneous boards are: TB-1 Extender, IMSAI MIO interface, and others. Comes with Infoton Vistar GTX video display. Software includes: 15 K Extended BASIC, Music System, games, etc. All manuals included. Over $5200 invested, first offer over $3300 takes everything. Steve Dover, 821 Laramie, Wilmette IL 60091, (312) 251-4683 evenings.

FOR SALE: Heath/Zenith disk software for H-17 disk system. I changed to CP/M, and have the latest HDOS 2.0 with Extended BASIC, editor, assembler, debugger, etc. With all manuals and binder, never run. Also, Microsoft BASIC for Heath H-8 or H-89 under HDOS. Latest version supports assembly-language subroutines. Never used. Either or both for half current catalog price. G Hammond, (603) 366-4012 evenings.

FOR SALE: Tano Outpost II 6800 computer. 48 K, two RS-232 I/O ports, two 5-inch Shugart disk drives, Tano BASIC, COPS II (utility programs), Hemingway editor, compiler, and link editor. Also, Flex II ROM, Flex II, editor, compiler, and debugger. Several disks and all manuals. $2000 or best offer. Arthur Shore, (415) 364-5006.

UNCLASSIFIED POLICY: Readers who are soliciting or giving advice, or who have equipment to buy, sell or swap should send in a clearly typed notice to that effect. To be considered for publication, an advertisement must be clearly noncommercial, typed double spaced on plain white paper, contain 75 words or less, and include complete name and address information.

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Please note that it may take three or four months for an ad to appear in the magazine.

FOR SALE: IMSAI PCS 80/30 with 48 K, dual single/double-density diskette drives (1 megabyte total), Intelligent keyboard (IKB-1), Leedex VT-100 monitor, and IMDOS. $4000 or best offer. Bill Levering, 26 Maple Rd, Westford MA 01886, (617) 692-3847.

FOR SALE: Apple II plus 64 K Pascal-language system, Zenith 13-inch color monitor, IDS-440 printer with graphics option, Hayes modem, dual disk drives, Mountain Clock, Controller, Cashier, Apple Writer, Apple Post, VisiCalc 1.37, Dow Jones Stock Evaluator, personal programs, and other accessories. $5900 complete. Fritz E Hockman, 45 Grampian Blvd, Williamsport PA 17701, (717) 326-4954 or 368-8631.

FOR SALE: Rockwell AIM-65 with 4 K programmable memory, ROM-based text editor/assembler, 8 K BASIC in ROM, power supply, and manuals. $475. Greg Vatt, 7170 S Lewis Way, Littleton CO 80127, (303) 979-1998.

FOR SALE: Terak 8510/a graphics computer system in perfect working condition. Includes DEC LSI-11 processor, 56 K programmable memory, 8-inch floppy drive, 240 by 320 black-and-white graphics on 12-inch video display, full ASCII keyboard, and UCSD Pascal software, including volumes 3 thru 5 of the USUS library. Excellent for schools, industry, or fanatic hobbyists. (Similar systems originally spawned UCSD Pascal.) Cost $8285 new; make offer. Jerome Wood, 6105 Harris, Raytown MO 64133, (816) 356-8290 after 5 PM weekdays.

WANTED: 16 K or 32 K Exidy Sorcerer/Sorcerer II computer. I am primarily interested in the computer itself, but will consider systems with peripherals (cassette or disk, printer, video monitor, etc). Please state asking price in first letter—will pay any reasonable price, depending on condition and age. Christopher Lett, 145 Meadow Ln, New Rochelle NY 10805.

FOR SALE: Pro-Log Z80 single-board computer, Model 7803, for the standard bus. This board is brand new—never been out of its protective package. $150 or trade for sailboat. Wayne Miller, 83 Brookwood Ct, Elgin IL 60120.

FOR SALE: Pascal Microengine computer manufactured by Western Digital Corp. The system is fully boxed and factory tested. This is not just a board; it is virtually unused. You get 64 K programmable memory and a processor that is optimized for the use of Pascal. Asking $3000, but will take the best offer. Robert Powers, 75 W Green St, Pasadena CA 91105, (213) 792-0893.

FOR SALE: Two complete SwTPC computers. Each has 24 K, MPS, MPC, MPL, JPC fast cassette, two tape decks, CT-64, 9-inch Sanyo, Fast BASIC with files, much software, and all cables. Ready to use. $800 each or $1500 for both, including PR-40 printer. Will trade for two CT-82 terminals. Howard Johnson, (207) 244-7444.

FOR SALE: 16 K Commodore PET computer, including external cassette drive, Programmer's Toolkit ROM, Soundware's Soundbox, and assorted programs. Game programs include Microchess 2.0, Super Startrek, Tanks, Othello, Backgammon, Breakout, and Bowling. Math programs include Infinite Long Division, Synthetic Division of Polynomials, and a polar-graph plotting routine. $900. Mike Sorna, 118 Georgetown Pl, McKeesport PA 15135, (412) 751-8075.

FOR SALE: SD Systems boards: SBC-200 Z80 processor; $280, VDB-8024 video controller; $300, Expandoram II 64 K; $250. All assembled and tested at factory, never used, 6 months old. Also, California Computer Systems mainframe, 12-slot motherboard, and power supply; $290. Xerox word-processing keyboard; $30. 10% off purchase of entire group. John A Maurer, (313) 884-0471.

FOR SALE: Recently purchased HP-41C system, including HP-41C calculator, two memory modules, printer with six rolls of paper, card reader with two packs of cards, rechargeable battery pack, and all manuals. $600. Paul Deines, POB 279, Marshalltown IA 50158, (515) 754-2177 work, 753-3661 home.

FOR SALE: Anderson Jacobson 242A acoustic coupler. Used, but in good condition. Best offer. Greg McDonald, 1434 Fenwick Ln, Silver Spring MD 20910, (301) 587-8536.

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BOMB

BYTE's Ongoing Monitor Box

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June BOMB Speaks Out

Steve Ciarcia's "Build a Low-Cost Speech-Synthesizer Interface" has talked its way into first place this month. Steve gets the $100 purse for his description of National Semiconductor's Digitalker speech-synthesis system. The article, obviously, left our readers speechless. The $50 second-place award goes to Gary Kildall for his article, "CP/M: A Family of 8- and 16-Bit Operating Systems," which describes the de facto standard "software bus." Robert Greenberg and James Larson tied for third place. Greenberg's "The UNIX Operating System and the XENIX Standard Operating Environment" provided an inside look at a large-computer operating system for microprocessors. Larson's article, "The Ins and Outs of CP/M," clarified and expanded on input/output and disk interfacing within the CP/M environment.

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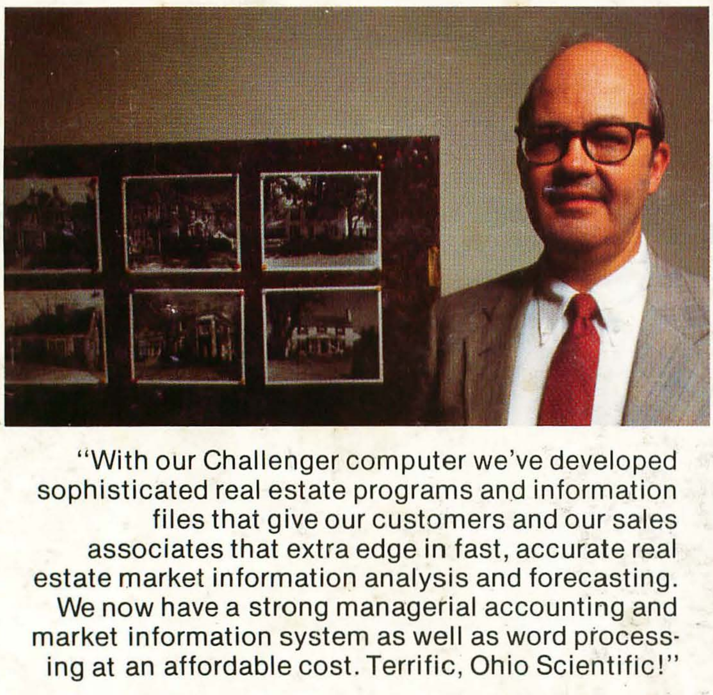

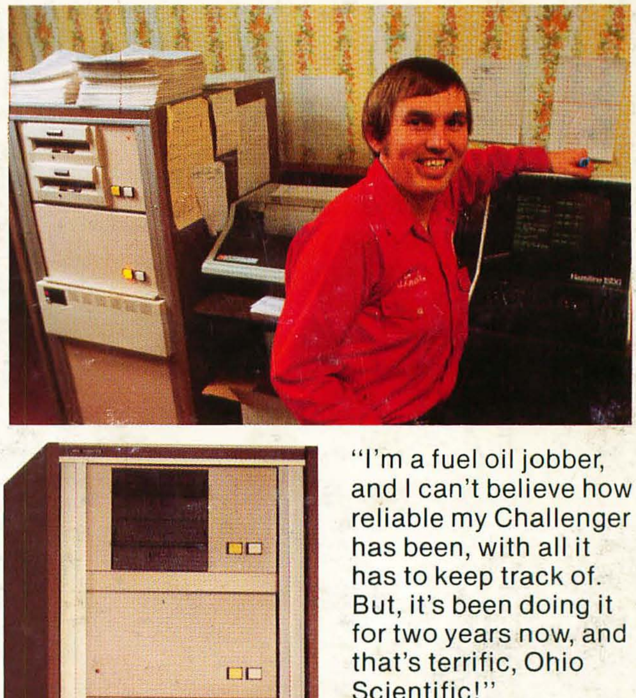

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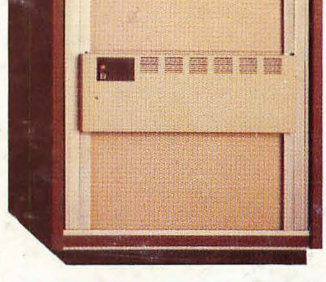

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